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EYE INJURIES IN CHILDHOOD AND THOSE CAUSED BY TOY GUNS, SPORT AND WOODEN PROJECTILES

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ACADEMIC DISSERTATION

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To Antti, Otso and Vuokko

ABSTRACT

Eye injuries cause inconvenience at least and permanent disability at worst. Yet most of the injuries are preventable. Therefore, it is essential to have updated information on the circumstances leading to eye injuries. By reporting on the causes and contexts, we can promote proper eye protection and safe behaviour to reduce the number of accidents.

In this thesis, the focus of analysis was leisure-time eye injuries; injuries in children and those caused by toy guns, sports and wooden projectiles in Southern Finland. Patients were gathered from all new eye trauma patients (n = 1151) taken into care at the Helsinki University Eye Hospital during a one-year period in 2011-2012. The background information was received via a questionnaire, and hospital records were accessed in order to gain complete information on status findings, treatments and resource use. The follow-up time was three months and patients injured by toy guns were examined also five years after the eye injury.

Children comprised 18 % (n = 202/1151) of all patients. Eye injury was most likely at the age of 13-16, and the leading causes were a hit of a sporting equipment (15 %), contact with the human body (12 %) and superficial foreign body (11 %). The main diagnosis was mild ocular or periorbital trauma (50 %). Six open globe traumas were caused by fireworks, tools, ski pole and a gun. Permanent disability was estimated for 9 % (n = 19) of children.

Toy guns caused 1 % (n = 15/1151) of all eye injuries, consisting of 12 airsoft guns, 2 peashooters and 1 paintball gun. The main diagnosis was contusion (87 %). At the five-year follow-up, 47 % (n = 7) had subjective impairment, and 53 % had (n = 8) abnormal clinical findings.

Sports caused 13 % (n = 149/1151) of all eye injuries. Floorball, football and tennis were the main sports to come up in the study. Floorball eye injuries decreased from 45 to 32 % of all sports-eye injuries from the season 2002-2003. The main diagnosis was contusion (77 %). Regarding participants, rink bandy had the highest risk. Permanent disability was diagnosed in 11 % of patients and was more common ($p = 0.033$) in ice hockey than in other sports in the number of injuries.

Wooden projectiles caused 6 % (n = 67/1151) of all eye injuries. Males aged 51-67 were at the highest risk. The most common activity during the accidents was playing (27 %), gardening (18 %) and forest work (16 %). In relation to time spent in the activity, the risk of eye injury was the highest in gardening, forest work and woodwork. Permanent disability was diagnosed for 10 % due to various activities.

Children should be guided safe play with sticks, and fireworks and tools should be avoided among children. The sale of toy guns should be more restricted and put under the Firearms Act to increase awareness of the risk. The use of eye protection in floorball is recommended for all age groups, and in ice hockey, the use of visors should be emphasised. In gardening, forest work and woodwork, the use of protective eyewear should be enhanced.

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications:

I Leivo T, Haavisto AK, Sahraravand A. Sports-related eye injuries: the current picture. Acta Ophthalmologica 2015; 93 (3): 224-231.

II Haavisto AK, Sahraravand A, Holopainen J, Leivo, T. Paediatric eye injuries in Finland. Helsinki eye trauma study. Acta Ophthalmologica 2017; 95 (4): 392-399.

III Haavisto AK, Sahraravand A, Puska P, Leivo T. Toy gun eye injuries -eye protection needed. Helsinki Ocular Trauma Study. Acta Ophthalmologica 2019; 2019; 97 (4): 430-434.

IV Haavisto AK, Sahraravand A, Holopainen J, Puska P, Leivo T: Eye injuries caused by wooden projectiles in Finland. Helsinki Ocular Trauma Study. Submitted.

The publications are referred to in the text by their roman numerals.

ABBREVIATIONS

AS/NZM	Standards Australia and Standards New Zealand
ASTM	American Society of Testing and Materials
BCVA	Best corrected visual acuity
BETTS	Birmingham eye trauma terminology system
FB	Foreign body
CSA	Canadian Standards Association
CT	Computer tomography
Dg	Diagnosis
EN	European Standard
HM	Hand movement
HUEH	Helsinki University Eye Hospital
ICD-10	International classification of diagnosis, tenth revision
IOFB	Intraocular foreign body
IOL	Intraocular lens
IOP	Intraocular pressure
ISO	International Organization for Standardization
JIS	Japanese Industrial Standards
LP	Light perception
LVA	Lowered visual acuity
mm	millimetre
MRI	Magnetic resonance imaging
NA	Data not available
NF	Need for follow-up
NFL	Nerve fibre layer
NLP	No light perception
NOCSAE	National Operating Committee on Standards for Athletic Equipment
OGT	Open globe trauma
Orbital fr	Orbital fracture
OTS	Ocular trauma score
PCO	Posterior capsule opacity
PD	Permanent disability
POTS	Paediatric ocular trauma score
RAPD	Relative afferent pupillary defect
TA	Applanation tonometry
Tot	Total number of patients
VA	Visual acuity
WHO	World Health Organisation

CONTENTS

1 INTRODUCTION

As a result of eye injuries blinding is estimated to comprise 1.6 million, bilateral low vision 2.3 million and unilateral or low vision 19 million people worldwide (Négrel, Thylefors 1998). In addition, eye injuries predispose to future complications in eye health such as an increased risk of glaucoma (Sihota, Sood et al. 1995, Gadia, Sihota et al. 2008). With proper use of eye protection, many eye injuries are preventable (Pizzarello 1998, Négrel, Thylefors 1998, Channa, Zafar et al. 2016). By preventing eye morbidity, the resources used for eye injury treatment can also then be used for other purposes.

With time, awareness of activities and equipment that harbours risk for eye health increased, unfortunately, only after eye injuries have occurred. Therefore, reporting potentially risky or occurred eye injuries is essential as a way to raise the discussion on the need for eye protection.

Children's eye injuries may have lifelong consequences and may influence their choice of future profession. Since the way of life and children's hobbies changed over time, it is important to update the current epidemiological data. Data of eye injuries in Finnish children is from 1981 (Niiranen, Raivio 1981).

Airsoft and paintball toy guns represent a relatively new type of leisure time activity, mostly common among young males. These guns shoot small plastic or liquid filled pellets at a high velocity. If proper protection is not used, these pellets cause severe eye injuries. There are no previous epidemiologic studies concerning eye injuries caused by toy guns in Finland.

Sport activities are a common cause of eye injury inducing 17 % of all eye injuries in Finland (Leivo, Puusaari et al. 2007). The epidemiology reflects the popularity of certain sports in relation to time and current culture. Sport injuries are often caused by trauma from sport equipment or a body part and most commonly causes blunt ocular trauma.

Wood as an independent cause of eye injury has infrequently been the focus of studies; the interest has been mostly on case reports and radiological problems identifying the wood. The factors that cause eye injuries must be identified in order to find ways to prevent them.

2 BACKGROUND

2.1 EPIDEMIOLOGY OF EYE INJURIES

The incidence of eye injuries needing hospital admission have varied from 8/1000 in the University Hospital in Sweden (n = 927) in 1986 to 2/100 000 in 2009 in ophthalmic departments in Scotland (n = 102) and 5/100 000 in Italy (n = 290) and 15/100 000 in Australia (n = 6308) (E Mönestam, U Björnstig 1991, Fong 1995, Cillino, Casuccio et al. 2008, Morris, Willis et al. 2014). Ocular traumas comprised 38 % (5671/14955) of all injuries treated in the Casualty Department in Glasgow (MacEwen, Caroline 1989). In the USA, the incidence of eye injuries in 2008 was 209/100 000, which resulted in an emergency department visit (Owens, Mutter 2006). In Canada, eye injuries that needed medical attention accounted for 2 % (104/4974) in a study based on telephone interviews, which also included treatment by optometrists and general practitioners (Gordon 2012).

In overall, determining the exact incidence of eye injuries is challenging since many eye injuries are not recorded. Many eye injuries are minor and are treated in primary care. In addition, some eye injuries are treated without any medical care.

2.1.1 EYE INJURIES IN CHILDREN

In children the incidence for hospitalized eye injuries have been 9/100 000 in Scotland (age 0-14 years) and 15/100 000 in the USA (age 0-15 years) (Strahlman, Elman et al. 1990, MacEwen, C. J., Baines et al. 1999). In Finland, children accounted for 35 % of all eye injury patients in 1981 and in Scotland 22 % in 1999 (Niiranen, Raivio 1981, MacEwen, C. J., Baines et al. 1999). In Italy, 11 % (32/298) of all hospitalized eye injury patients were boys under 10 years of age in a 5-year study period (Cillino, Casuccio et al. 2008).

Causes

Typical children's eye injuries comprise accidental falls or trauma from a projectile. In the USA, falls and hits accounted for 37 % (62/167) of hospitalized patients in 1990 and 34 % (17 299/376 040) of all children emergency department visits in 2018 (Strahlman, Elman et al. 1990, Matsa, Shi et al. 2018). In Australia being struck or hit by on object accounted 53 %, however, falls for less than 5 % of paediatric eye injuries that required hospitalization (Yardley, Hoskin et al. 2017).

In Finland, according to the latest epidemiological data from 1981, projectiles accounted for 21 % of eye injuries. A hit from a snowball was the single biggest group (Niiranen, Raivio 1981). In Denmark, airsoft guns accounted for the largest percentage, 17 %, of all children's eye injuries (Saunte, Saunte 2008). Sports or sport equipment is often reported as a cause, accounting for 9-27 % of eye injuries (Niiranen, Raivio 1981, Strahlman, Elman et al. 1990, MacEwen, C. J., Baines et al. 1999, Yardley, Hoskin et al. 2017).

Consumer product-caused ocular and periocular eye injury cases of over 21 000 infants

(0-12 months of age) in the USA were analysed in a study by Chen et al. (2013). Among infants chemicals accounted for 46 %, household items 24 %, furniture 13 % and toys 11 % (Chen, Linakis et al. 2013). In other studies, furniture has been a reason in 9 % and toys in 12 % of hospitalized patient cases up to 16 and 14 years of age in Australia and Scotland (MacEwen, C. J., Baines et al. 1999, Yardley, Hoskin et al. 2017).

Type of injury

Contusion as a primary diagnosis was noted in 21-65 % and open globe trauma (OGT) in 4-24 % of hospitalized paediatric patient cases in the USA, Scotland, Australia and Hong Kong (Strahlman, Elman et al. 1990, Desai, P., MacEwen et al. 1996, Poon, ASY, Ng et al. 1998, MacEwen, C. J., Baines et al. 1999, Yardley, Hoskin et al. 2017). Of all patients, OGT accounted for 9 % and 16 % of all traumas in studies performed by Niiranen (1981) and Strahlman et al. (1990). In the study by Niiranen (1981), blunt ocular trauma accounted for 66 %, superficial eye injury 14 % and eyelid wound 12 % of all eye injuries.

Outcome

The outcome of eye injuries can be seen in Table 1. In the study by Sarazzin et al. (2004), the detachment of macula predicted the worse outcome (Sarrazin, Averbukh et al. 2004).

Table 1. The outcome of eye injuries in children in previous studies.

Author (year), country	No. of patients	Lowered VA	Limit of lowered VA	Interest of study	Follow-up time
Niiranen, Raivio (1981), Finland	110	7 %	< 0.5	All children	NA
MacEwen et al. (1999), Scotland	93	2 %	< 0.5	All children	≥ 3 months
Sarazzin et al. (2004), Israel	34[a]	77 %	< 0.1	Traumatic retinal detachment after OGT	2 months-12 y (average 3.1 y)
Sarazzin et al. (2004), Israel	20[b]	55 %	< 0.1	Traumatic retinal detachment after contusion	1 month - 10 y[c]
Bunting et al. (2013), Canada	131	44 %	< 0.5	OGT	2 y

[a] = 37 eyes of 36 patients in the study, 3 patients did not receive surgery and were not included to the outcome results: 35 eyes of 34 patients
[b] = 22 eyes
[c] = In 12 of the eyes
VA = Visual acuity
NA = Data not available
y = Years
OGT = Open globe trauma

2.1.2 EYE INJURIES CAUSED BY TOY GUNS

Toy guns are popular toys in children's play as is paintball in adults' leisure time. Airsoft guns, also called pellet guns, resemble real guns in appearance and shoot 6 mm plastic pellets. Paintball pellets are larger, 17-18 mm spherical balls containing liquid (Nemet et al. 2016). Both can reach a velocity of up to 110 m/s (Duma, Kennedy 2006, Kennedy et al. 2008). Peashooters are often self-made from e.g. a plastic tube; the pea is blown through the tube or shot by stretching a finger on a rubber glove, which is attached to the tube.

In the USA, in a study of sports-related eye injuries (n = 120 847), projectile firing devices accounted for 10 % of all eye injuries but resulted in impaired vision in 26 % of patients. Though, it should be noted that firing devices also included air guns (Haring, Sheffield, Canner et al. 2016). In a study from Hong Kong, toy guns were the cause for eye injury in 12 % (7/60) of paediatric patients who required hospitalization (Poon, ASY, Ng et al. 1998).

A hit from a toy gun typically causes blunt ocular trauma and may even cause open globe traumas (Fleischhauer, Goldblum et al. 1999, Saunte, Saunte 2006, Ramstead, Ng et al. 2008, Kratz 2010, Jovanovic, Bobic-Radovanovic et al. 2012).

2.1.2.1 Airsoft guns

Airsoft is a type of fighting game originating from Japan, where participants shoot each other using an airsoft gun. The pellet is shot from an air-loaded gun that resembles a real gun. The pellet is round, plastic, 6mm in diameter and weights 0.2-0.43 g. The obtained kinetic energy is 0.4J (Fleischhauer, Goldblum et al. 1999, Endo, Ishida et al. 2000). Airsoft is often played as an arranged game, but the guns are also used in children's plays.

It is notable that in Japanese literature, ball bearing (BB) guns refer to airsoft guns that fire plastic pellets, whereas in European and American literature, BB guns are known to use metallic pellets (Endo, Ishida et al. 2000). In this thesis, airsoft guns will be considered to fire plastic pellets.

The incidence of airsoft-related eye injuries has been reported to be from 0.3 eye injuries/100 000 population in Denmark (Saunte, Saunte 2006) to 2.5 /100 000 in Israel (Kratz 2010). Patients are typically young males with the mean age of 9 to 14 (Fleischhauer, Goldblum et al. 1999, Saunte, Saunte 2006, Kratz 2010, Shazly, Al-Hussaini 2012, Jovanovic, Bobic-Radovanovic et al. 2012, Rambaud, Tabary et al. 2013).

Eye injuries caused by airsoft are often severe. In Denmark, 3.6 % of all severe eye trauma was caused by airsoft guns (Saunte, Saunte 2006). Hospitalization was needed in 10 % of airsoft gun-related eye injuries in Israel (Kratz 2010). In Serbia, 3 % of hospitalized eye injury patients were injured by airsoft guns, the hospitalization lasting for an average of 6 days (taken from 1-18 days) (Jovanovic, Bobic-Radovanovic et al. 2012). The need for surgical intervention was 3 % in a ten-year retrospective study of 92 patients in Serbia (Jovanovic, Bobic-Radovanovic et al. 2012).

The typical ocular diagnoses include corneal donut-shaped erosion and oedema, hyphema, iris trauma, raised intraocular pressure (IOP), vitreous haemorrhage, retinal oedema and haemorrhage (Fleischhauer, Goldblum et al. 1999, Endo, Ishida et al. 2001, Saunte, Saunte 2006, Ramstead, Ng et al. 2008, Saunte, Saunte 2008, Kratz 2010, Shazly, Al-Hussaini 2012, Jovanovic, Bobic-Radovanovic et al. 2012, Adyanthaya, Chou et al. 2012, Gupta, Tailor

et al. 2018). OGTs have also been reported (Adyanthaya, Chou et al. 2012, Jovanovic, Bobic-Radovanovic et al. 2012, Gupta, Tailor et al. 2018).

Clinical findings in airsoft gun eye injuries in previous studies are shown in Table 2. Hyphema, irideal trauma and posterior findings are common observations in all studies.

Lowered visual acuity (VA) was reported in a retrospective study of Jovanovic et al. (2012); 9 % had a VA 0.3 Snellen equivalent or less, and 16 % had final VA less than 0.8 Snellen equivalent at the time of discharge (1-18 days) (Jovanovic, Bobic-Radovanovic et al. 2012). In the study by Kratz (2010), the final VA after a mean follow-up of 8 months was 0.8 Snellen equivalent, though one patient with traumatic cataract was lost to follow-up (Kratz 2010).

Table 2. Previous studies of airsoft gun-related eye injuries, main clinical findings of the studies and the need for surgery.

Author (year), country	N	Mean age (years)	Hyphema % (n)	Irideal trauma % (n)	Traumatic cataract % (n)	IOP elevation[1)] % (n)	Post. findings % (n)	Surgery % (n)
Fleischauer et al. (1999), Switzerland	9	14	78 % (7)	55 % (5)[2)]	33 % (3)	22 % (2)	55 % (2)	11 % (1)
Saunte and Saunte (2006), Denmark	33	14	84 % (28)	58 % (19)[2)]	3 % (1)	12 % (4)	36 % (11)	3 % (1)
Ramstead and Rudinsky (2008), Canada	8	18	100 % (8)	75 % (6)	13 % (1)	0 %	13% (1)	13 % (1)
Kratz (2010), Israel	59	10	66 % (39)	25 % (15)	2 % (1)	2 % (1)	24 % (14)	0 %
Jovanovic et al. (2012), Serbia	92	14	98 % (90)	11 % (10)	1 % (1)	29 % (27)	54 % (51)	3 % (3)

[1)] IOP elevation was mentioned, but the exact limit of elevated intraocular pressure lacked in all studies.
[2)] Includes both traumatic mydriasis and irideal dialysis.
IOP = Intraocular pressure
Post findings = Posterior findings: vitreous haemorrhage, retinal haemorrhage, retinal oedema, choroidal rupture and one globe rupture [Jovanovic et al. (2012)].

2.1.2.2 Paintball

Paintball is a game played with guns that resemble real weapons but use liquid-containing pellets that explode on impact. The aim of the game is to mark another player with paint from the pellet. The pellet is 16-17 mm in diameter and may reach a velocity up of to 113 m/s (Kennedy, E. A., Stitzel et al. 2008). Paintball games are often organised in a restricted area, and the players wear protective gear.

The incidence of paintball-related injuries in emergency departments in the USA from 1997-2001 was 4.5/10 000 participants (95 % CI 3.3-5.7), and an eye was affected in 43 % (Conn, Annest et al. 2004). In 2008, 1200 paintball eye injuries were reported in one year in USA emergency clinics (Kennedy, E. A., Stitzel et al. 2008), and in a two-year period (1996-

1998), 4 % (11/264) of all severe eye injuries were caused by paintballs (Kitchens, Danis 1999). Eye injuries take place mostly during a game (53 %; 11 % during formal, 42 % during informal game), but may also occur as accidents or assault (Greven, Bashinsky 2006).

Participants are often older than in airsoft, mean age of 5-24 years of age (Kitchens, Danis 1999, Thach, Ward et al. 1999, Fineman, Fischer et al. 2000, Greven, Bashinsky 2006, Baath, Ells et al. 2007, Lee, K. M., Seery et al. 2017).

A hit from a paintball typically causes severe contusion and rupture of an eyeball (Kitchens, Danis 1999, Thach, Ward et al. 1999, Fineman, Fischer et al. 2000, Greven, Bashinsky 2006, Baath, Ells et al. 2007, Nemet, Asalee et al. 2016, Lee, K. M., Seery et al. 2017). Traumatic optic neuropathies have also been reported (Thach et al. 1999). The main clinical findings in previous studies are shown in Table 3.

Table 3. Previous studies of paintball-related eye injuries, main clinical findings of the studies and need for surgery.

Author (year), country	N	Mean age (years)	Hyphema	Irideal trauma	Traumatic cataract	IOP elevation	Posterior findings	Surgery	OGT
			% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
Fineman et al. (2000), USA	35	22	60 % (21)	3 % (1) [1]	20 % (7)	17 % (6)[2]	80 % (28)	40 % (14)	6 % (2)
Baath et al. (2007), Canada	3	15	100 % (15)	33 % (1)	33 % (1)	66 % (2)	100 % (3)	33 % (1)	0 %
Greven et al. (2006), USA	19	16[3]	100 % (19)	26 % (5)	37 % (7)	NA	[4]	NA	11 % (2)
Thach et al. (1999), USA	13	21	69 % (9)	31 % (4)	31 % (4)	8% (1)[5]	[6]	85 % (11)	23 % (3)
Nemet et al. (2016), Israel	5	21	80 % (4)	80 % (4)	60 % (3)	60 % (3)	100 % (5)	80 % (4)	0 %

Posterior findings: vitreous haemorrhage, retinal haemorrhage/commotio/rupture/detachment/dialysis, choroidal rupture, macular hole
IOP = Intraocular pressure
OGT = Open globe trauma
NA = Data not available
[1] Mentioned only in one case among the main findings
[2] 17 % had traumatic glaucoma.
[3] Mean age of 18 male patients (95 % of patients)
[4] 46 % had vitreous haemorrhage, 37 % had commotio retinae and 26 % had iridodialysis, choroidal rupture or retinal detachment.
[5] > 21 mmHg
[6] 69 % had vitreous haemorrhage, 46 % had retinal detachment and 23 % choroidal rupture.

Paintball eye injuries have been reported to cause visual impairment. The final VA was 0.1 Snellen equivalent (20/200) in 62 % (n = 8) of patients because of retinal detachment, optic neuropathy, epiretinal membrane, cataract, corneal oedema, subfoveal neovascu-

larisation and retinal necrosis in a report by Thach et al. analysing 13 patients in the USA (Thach, Ward et al. 1999). In a study of 19 patients 37 % (n = 9) ended up as legally blind in another study from the USA (Greven, Bashinsky 2006). Visual acuity from 0.25 Snellen equivalent (20/80) to hand movement 2-14 months after the trauma was reported in three patients and final VA of less than 0.1 Snellen equivalent (10/100) three out of five patients in case reports from Canada and Israel (Baath, Ells et al. 2007, Nemet, Asalee et al. 2016). A case report of four patients with secondary glaucoma and a VA of less than 0.05 Snellen equivalent (20/400) due to paintball eye injuries was reported from Israel (Lee, K. M., Seery et al. 2017). These results show that paintballs can indeed cause severe visual impairment.

2.1.2.3 Other toy guns

There are also other toy guns in addition to those mentioned above. In Finland, Nerf Guns are also popular among young children. Nerf Guns are toy guns that shoot foam bullets with a hard plastic end. In the United Kingdom (UK), there is a case report including three patients harmed by a Nerf Gun (Bizrah, Verma 2017); among the reported injuries, there were contusions, including corneal oedema, hyphema, localised angle recession, uveitis and commotio of retinae.

There are no epidemiological data or case reports concerning pea shooter eye injuries.

2.1.3 EYE INJURIES CAUSED BY SPORTS

Sports have been the cause of eye injuries in 17 % (94/565) of cases in Finland (6-month study period) and in 14 % (76/553) in Norway (10-year study period) (Drolsum 1999, Leivo, Puusaari et al. 2007). Of ocular contusions, 40 % (109/272) were sport-related in a 2.5-year period in Sweden (Ghosh, Bauer 1995)

In the USA, 5 % (120 846/2.6 million) of all eye injuries treated in emergency departments, 3 % (n = 85 961) of them being primary diagnoses, were sports-related, as determined in a large-scale study covering data from over 900 hospitals and 30 million emergency visits (Haring, Sheffield, Canner et al. 2016). In the UK, 0.3 % (48/16 999) of all patients treated in the emergency department of an ophthalmic hospital were sports-related eye injuries (Ong, Barsam et al. 2012).

Patients injured by sports are often young males. The reported mean age has been from 22 to 26 years (Gregory 1986, Filipe, Barros et al. 1997, Drolsum 1999, Haring, Sheffield, Canner et al. 2016).

In children, sport injuries comprise 14-19 % of all eye injuries in Finland, the USA and Australia (Niiranen, Raivio 1981, Owens, Mutter 2006, Hoskin, Yardley et al. 2016) . The incidence of serious children's eye injuries caused by sports was 8.5/year in Australia (Hoskin, Yardley et al. 2016).

Seasonal variation has been significant in some studies. In Portugal, injuries occurred more often in March, and in Australia, in spring and summer months (Filipe, Barros et al. 1997, Hoskin, Philip et al. 2016).

In Scandinavia, the popularity of floorball corresponds with eye injuries: floorball is considered the cause in 45 % of all sports-related eye injuries in Finland, 56 % in Sweden

and 17 % in Norway. Other sports known to cause eye injuries in Nordic countries include football, tennis and badminton (Drolsum 1999, Leivo, Puusaari et al. 2007, Bro, Ghosh 2017). Basketball is the main cause in the USA, and football in Scotland and Portugal (MacEwen, Caroline 1989, Filipe, Barros et al. 1997, Kim, T., Nunes et al. 2011, Haring, Sheffield, Channa et al. 2016). Though, in the USA, football causes the most visual impairments (Haring, Sheffield, Canner et al. 2016).

In relation to participants, floorball in Norway and squash in Finland have been the most dangerous to eyes (Drolsum 1999, Leivo, Puusaari et al. 2007). In another study from Finland, basketball caused the most eye injuries, but floorball was not yet popular at the time and was not included in the study (Kujala, Taimela et al. 1995).

In the USA and Australia, sports are categorized according to high, moderate and low risk based on popularity and incidence of eye injuries or whether the sport includes hard, dense projectiles, fingers close to eyes, use of a stick, a racket or a hand (Committee on Sports Medicine and Fitness, American Academy of Ophthalmology et al. 2004, Dain 2016). The list can be seen in Table 4.

Table 4. Modified list of sports endangering eye health in the USA and in Australia. Kim et al. (2011) and Dain et al. (2016).

USA	Australia
High risk	High risk
BB-gun and paintball	Air rifle and paintball
Basketball	Badminton
Baseball	Baseball/Softball
Softball	Basketball
Ice hockey	Ice hockey
	Squash
	Tennis
Moderate risk	Moderate risk
Tennis	American football
Soccer	Rugby
Volleyball	Soccer
Football	Volleyball
Fishing	
Golf	
Low risk	Low risk
Swimming	Jogging, running, aerobics
Snow and water skiing	Cycling
Cycling	Skiing
Eye-safe	Swimming
Jogging, running, aerobics	

BB gun = a type of airgun that shoot metallic ball-shaped projectiles.

The reason for sports-related eye injury is often contact with a flying projectile (ball,

puck etc.), sports equipment or a co-player, seldomly done to one's self. The ball is responsible for the most (64-73 %) of eye injuries (Gregory 1986, MacEwen, Caroline 1989, Filipe, Barros et al. 1997, Drolsum 1999). A stick or club accounts for 13-25 % (Gregory 1986, Drolsum 1999) and contact with a co-player, for example, contact with a fist or elbow, accounts for 4-16 % (Filipe, Barros et al. 1997, Drolsum 1999). In children, balls account for 22 % and sports equipment slightly more with 28 % of eye injuries. Contact with another person was the reason for 76 % of orbital fractures in children (Hoskin, Yardley et al. 2016).

Contusion was a diagnosis in 77-87 % of sports-related eye injuries treated by ophthalmologists (Drolsum 1999, Leivo, Puusaari et al. 2007), 30 % when taking into account all emergency department visits (Ghosh, Bauer 1995, Drolsum 1999, Leivo, Puusaari et al. 2007). In children, contusion accounted for 18 % of sports-related injuries in a study by Hoskin et al. (2016) (Hoskin, Yardley et al. 2016).

Hyphema is found in up to 81 % of patients (Gregory 1986, MacEwen, Caroline 1989, Ghosh, Bauer 1995, Filipe, Barros et al. 1997, Drolsum 1999, Leivo, Puusaari et al. 2007) and posterior findings (retinal oedema, retina haemorrhage, retinal tear/detachment) are found in 11-44 % of patients (Gregory 1986, MacEwen, Caroline 1989, Filipe, Barros et al. 1997, Drolsum 1999). Adnexal and superficial injuries, iris trauma and IOP elevation are common, while open globe trauma is rare but still reported in many studies (MacEwen, Caroline 1989, Ghosh, Bauer 1995, Leivo, Puusaari et al. 2007, Hoskin, Philip et al. 2016) (Table 5).

Permanent disability is reported in 6–31 % of sport-related eye injuries (MacEwen, Caroline 1989, Ghosh, Bauer 1995, Filipe, Barros et al. 1997, Drolsum 1999). In the study by Drolsum (1999), 10 % of patients had lowered VAs as a result of optic nerve damage, choroidal rupture, macular scar, retinal detachment and vitreous haemorrhage with glaucoma (Drolsum 1999). In a study by Filipe et al. (1997) including 84 patients, 31 % had a VA 0.4 Snellen equivalent (20/50) or worse due to corneoscleral laceration, retinal detachment, proliferative retinopathy, contusion maculopathy and choroidal rupture (Filipe, Barros et al. 1997). A smaller rate of permanent disability can be found in studies in Scotland with a final VA 0.3 Snellen equivalent (6/18) or less in 9 % (MacEwen, Caroline 1989), and in Sweden, with a final VA less than 0.5 Snellen equivalent in 6 % of patients 3-6 months after the injury (Ghosh, Bauer 1995). More severe traumas have been related to injuries caused by bats than the ball in floorball (Ghosh, Bauer 1995).

Table 5. Previous studies concerning eye injuries caused by sports: age, main clinical findings and need for surgery.

Author	N	Mean age (range), years	Contusion % (n)	Hyphema % (n)	IOP ↑ % (n)	Iris trauma % (n)	Cataract % (n)	Post. findings % (n)	OGT % (n)	Surgery % (n)
Gregory et al. (1986), England	92	NA	NA	22% (20)	NA	NA	NA	18% (17)	0	NA
MacEwen (1989), England	131	NA	NA	16% (21)	NA	NA	0	11% (14)	1% (1)	NA
Ghosh et. al (1995), Sweden	109	66% 10-29	100 %	46% (50)	7% (8)	9% (10)	1% (2)	44% (48)	0	NA
Filipe et al. (1997), Portugal	84	26 (11-48)	NA	54% (45)	29% (24)	4% (3)	NA	44% (37)	2% (2)	18% (15)
Drolsum (1999), Norway	76	25 (7-59)	87 % (66)	NA	NA	NA	1 % (1)[1)]	NA	1% (1)	7% (5)
Leivo et al. (2007), Finland	94	NA	NA	54 % (51)	15% (14)	19% (18)	3% (3)[2)]	44% (41)	1% (1)	11% (10)
Hoskin et al. (2016), Australia	93	9 (1-16)	18% (17)	NA	NA	NA	NA	NA	7% (6)	49% (46)

IOP ↑ = Elevation in intraocular pressure
Post. findings = Posterior findings
OGT = Open globe trauma
NA = Data not available
[1)] One patient underwent cataract surgery.
[2)] Lens opacities mentioned in three patients.

2.1.4 EYE INJURIES CAUSED BY WOODEN ITEMS

Sticks or wood have caused 4 % of all eye injuries in adults in Finland and 6 % in Canada (Gordon 2012, Sahraravand, Haavisto et al. 2017). Of penetrating eye injuries, those caused by wooden items comprised 33 % in Denmark (Saunte, Saunte 2008). A hit from a wooden object caused most penetrating eye traumas in elderly (65-90 years) people in Turkey (Yüksel, Türkcü et al. 2014). Branches, sticks, bushes, pencils, corn stalks and other treated wood objects have been reported to cause intraorbital injuries in all age groups (Shelsta 2010, Tas, Hüsamettin 2014, Li et al. 2016).

In children, sticks have caused 6 % of eye traumas in Finland, 12 % in Brazil and up to 27 % in Nigeria (Niiranen, Raivio 1981, Nonso Ejikeme Okpala, Rich Enujioke Umeh et al. 2015, Rohr, Santos et al. 2016). Open globe injuries have resulted from bamboo sticks, wooden branches and pencils in Denmark (Saunte, Saunte 2008). Poor visibility of wood

in radiologic imaging may delay the diagnosis. (Specht, Varga et al. 1992, Liu, D. 2010, Kim, Usha R., Sivaraman 2013, Desai, A., Parihar et al. 2014, Li, J., Zhou et al. 2016).

As an organic material, wood entails a risk of infection by rare microbes. In Table 6, case reports of injuries caused by wooden materials can be seen (Lai, T. Y., Kwok et al. 2001, Taylor, Wiffen et al. 2002, Chew, Jungkind et al. 2010, Liu, M., Xin et al. 2015, Clark, Fernandez de Castro, J P et al. 2016).

Table 6. Examples of infections caused by wooden particles in the eye or the periocular area. All patients were immunocompetent.

Author (year), country	Incident	Microbe	Infection	End result
Lai et al. (2001), Hong Kong	Hit by a wooden splinter	*Stenotrophomonas maltophilia (gram-negative bacteria)*	Endophthalmitis	Healed, VA 0.7
Taylor et al. (2002), Australia	Chopping wood	*Scedosporium inflatum* (fungi)	Corneal laceration, endophthalmitis	Enucleation
Chew et al. (2010), USA	Cutting wood outdoors	*Carpoligna pleurothecii* (fungi)	Corneal laceration: keratitis	Corneal scar, aphakia
Liu et al. (2015), China	Struck by a piece of wood	*Rhinoclasidiella basitona* (fungi)	Corneal laceration: endophthalmitis	Corneal transplant
Clark et al. (2016), USA	Car accident	*Cedecea* (gram-negative bacteria)	Intraorbital fb: orbital cellulitis, corneal ulcer	Healed

2.2 CLASSIFICATION AND DEFINITION OF EYE INJURIES

2.2.1 BIRMINGHAM EYE TRAUMA TERMINOLOGY (BETT)

Birmingham Eye Trauma Terminology (BETT) is a standardized system to describe mechanical injuries of the eye. First, it is determined if the trauma is open or closed and the issue is continued further into following subcategories. In cases where the trauma contains features of several subcategories, the most appropriate type is chosen.

Special attention has been paid to define each term unambiguously in order to avoid a misunderstanding of the different trauma types. In Figure 1, the classification can be seen, and in Table 7, the explanation of the terms is given. (Kuhn, Ferenc, Morris et al. 1996, Kuhn, F., Morris et al. 2002).

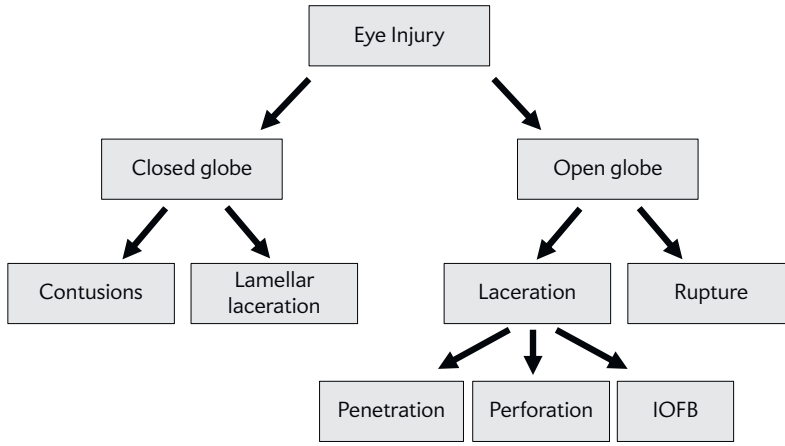


Figure 1 . Classification of eye injuries according to the Birmingham Eye Trauma Terminology BETT) system (IOFB = Intraocular foreign body).

Table 7. Definition of terms in the BETT system by Kuhn et al. (2004).

Term	Definition
Closed globe trauma	No full thickness wound of sclera or cornea
Contusion	Kinetic energy elevates intraocular pressure without causing the full thickness tearing of the cornea or sclera
Lamellar laceration	Partial thickness wound of sclera or cornea
Open globe trauma	Full thickness wound of sclera or cornea
Laceration	
Penetration	Only entrance wound exists
Perforation	Both entrance and exit wound exist
IOFB	Entrance wound. Foreign object remains inside the eye
Rupture	Kinetic energy elevates intraocular pressure and causes break to orbital wall

IOFB = Intraocular foreign body

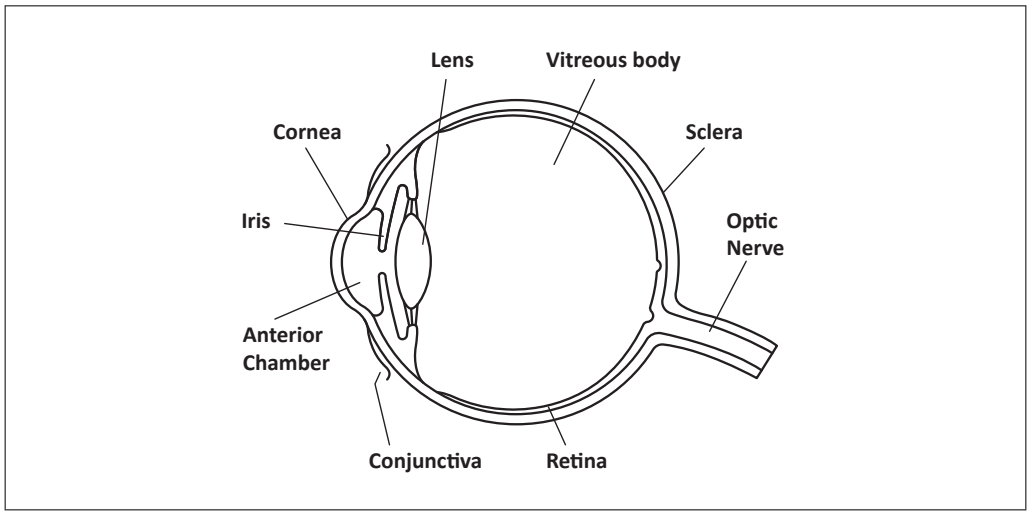


Figure 2. Horizontal view of the eye.

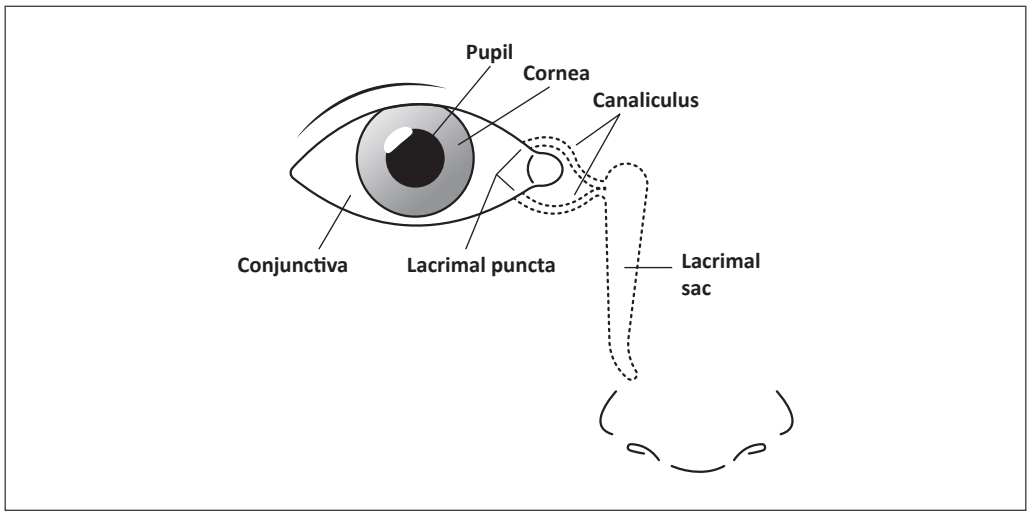


Figure 3. Anterior view of the eye and canalicular system.

2.2.1.1 Closed globe trauma

Contusion

In contusions, the impact to the eye comes from outside towards the inside and causes damage inside the eyeball (Kuhn, Ferenc, Morris et al. 1996, Kuhn, F., Morris et al. 2002). The cause is often a hit from a blunt object.

The incidence of contusions was 25/100 000 in the USA in Emergency Departments and

2.5/100 000 in Italy, but both also includes adnexal contusions (Ramirez, Porco et al. 2018, Cillino, Casuccio et al. 2008).

In children, contusions accounted for 21-65 % and in sports 77-87 % of all eye injuries treated by ophthalmologists (Strahlman, Elman et al. 1990, Desai, P., MacEwen et al. 1996, Drolsum 1999, MacEwen, C. J., Baines et al. 1999, Thompson, Kumar et al. 2002, Leivo, Puusaari et al. 2007, Yardley, Hoskin et al. 2017).

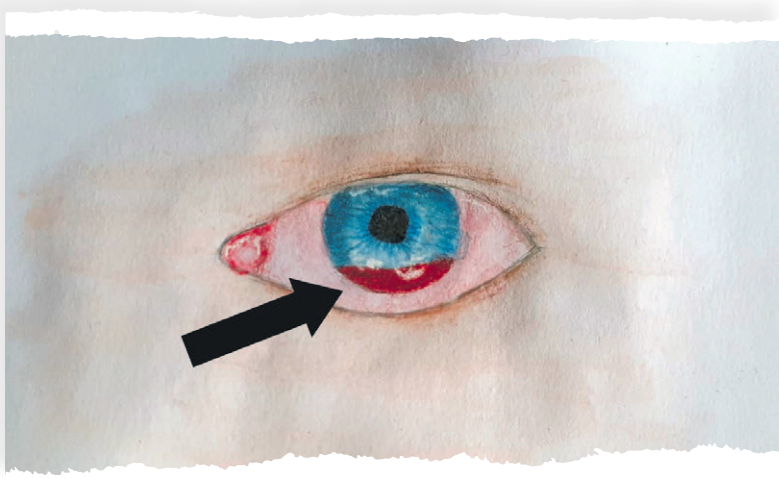


Figure 4. Blood in anterior chamber (hyphema, arrow) is a common clinical finding in contusion.

Lamellar laceration

Lamellar laceration is a partial severe wound or trauma in the cornea or sclera. Minor injuries such as erosions or superficial foreign bodies are not included. Lamellar lacerations accounted for 1 % of all closed globe traumas in the study by Wang et al. (2017). In the studies by Karaman et al. (2014) and Yardley et al. (2017), they accounted for 13 % of closed globe traumas, but there is suspicion that corneal abrasions and foreign bodies are included in this number.

2.2.1.2 Open globe trauma

OGT means a full thickness wound of the sclera or cornea. OGT is divided into laceration and rupture. Laceration is divided further into penetration, perforation and intraocular foreign body (IOFB).

The incidence of OGTs has varied from 2.4 to 4.6/100 000 in Denmark, Italy, New Zealand, Australia and the USA (Fong 1995, Cillino, Casuccio et al. 2008, Vestergaard, Søltoft et al. 2015, Court, Lu et al. 2019, Ramirez, Porco et al. 2018). In Japan, lacerations accounted for 45 % and ruptures 55 % of OGTs (Yoshifumi Okamoto, Shohei Morikawa et al. 2019).

In children, OGTs have accounted for 16-24 % of hospitalized paediatric patients due to eye injury in the USA, Scotland and Australia (Strahlman, Elman et al. 1990, Desai, P., MacEwen et al. 1996, MacEwen, C. J., Baines et al. 1999, Thompson, Kumar et al. 2002, Yardley, Hoskin et al. 2017). In sports, OGT was reported up to 1 % and in paintball up to 6-23 % of eye traumas (Drolsum 1999, Thach, Ward et al. 1999, Fineman, Fischer et al. 2000, Capao Filipe, Fernandes et al. 2003, Greven, Bashinsky 2006, Leivo, Puusaari et al. 2007). In airsoft, OGTs are single cases (Adyanthaya, Chou et al. 2012, Jovanovic, Bobic-Radovanovic et al. 2012, Gupta, Tailor et al. 2018). Wooden splinters, branches and logs caused 24 % of OGTs in Croatia (Karaman, Gverović-Antunica et al. 2004).

Penetration

Penetration has accounted for 35-71 % of OGTs in all age groups and less (13 %) among children (Vestergaard, Søltoft et al. 2015, Karagöz, Sari et al. 2018, Court, Lu et al. 2019).

Perforation

Perforations are the minority in OGTs, reported in 0.7 % of all OGTs in adults, 1.3 % of all OGTs in sports and 0.2 % of all eye injuries in the paediatric population (Drolsum 1999, Yardley, Hoskin et al. 2017, Karagöz, Sari et al. 2018).

IOFB

IOFB is not always easy to distinguish from penetration. Suspicion should arise during anamnesis and then be confirmed with radiology (Fulcher, McNab et al. 2002, Dasgupta, Vats et al. 2015, Li, J., Zhou et al. 2016).

The incidence has been 0.16/100 000 in patients treated by ophthalmologists in a prospective study of a one-year period in the UK and 0.8/100 000 in emergency departments in the USA and in the UK (Imrie, Cox et al. 2008, Ramirez, Porco et al. 2018). Of all OGTs, IOFB has accounted for 16-34 % (Cillino, Casuccio et al. 2008, Falcão, Camisa et al. 2010, Zhang, Zhang et al. 2011, Liu, C. C. H., Tong et al. 2017). Hammering is considered to be the most common aetiology (35-64 %) and metallic foreign bodies the most common causative agent (50-74 %) in many studies (Lai, Y. K., Moussa 1992, Imrie, Cox et al. 2008, Falcão, Camisa et al. 2010, Zhang, Zhang et al. 2011, Konforty, Lior et al. 2016, Liu, C. C. H., Tong et al. 2017).

Rupture

Rupture is caused by a blunt object, which elevates the IOP when hitting the eyeball, and brakes the orbital wall (sclera or cornea) from the weakest part, which can be other than the impact from the object, for example, previous surgery incisions (Kuhn, Ferenc, Morris et al. 1996).

Globe ruptures have accounted for 29-57 % of OGTs (Vestergaard, Søltoft et al. 2015, Li, E. Y., Chan et al. 2017, Karagöz, Sari et al. 2018, Yoshifumi Okamoto, Shohei Morikawa et al. 2019).

Rupture has been the most common type of OGT in women in a Danish (63 % of all

OGTs) and Japanese study (80 % of all OGTs) (Vestergaard, Søltoft et al. 2015, Yoshifumi Okamoto, Shohei Morikawa et al. 2019). Wooden splinters and branches caused 26 % of adult ruptures in Croatia (Karaman, Gverović-Antunica et al. 2004).

2.2.2 OTHER TRAUMA –TYPES (NOT CATEGORIZED IN BETT)

Many ocular and periocular injuries are not categorized in BETT and treated by or alongside ophthalmologists in Finland at least and are therefore included in this thesis.

2.2.2.1 Minor corneal and conjunctival injuries

Minor corneal and conjunctival injuries are often treated by general practitioners. In the emergency department in the USA, corneal abrasion and superficial laceration of the eye or its adnexal accounted for most (38 %) eye injuries (Channa, Zafar et al. 2016). The incidence of corneal abrasion was 87/100 000 in a cross-sectional study of emergency department visits for ocular trauma in the USA (Ramirez, Porco et al. 2018).

As treated by ophthalmologists, extra orbital foreign bodies accounted for 56 % and corneal abrasions 25 % of all eye injuries (MacEwen, Caroline 1989). Among children, corneal abrasions accounted for 3 % of all children's eye injuries, and in sports, superficial injuries accounted for 5-6 % of all sports-related eye injuries (Niiranen, Raivio 1981, Drolsum 1999, Leivo, Puusaari et al. 2007).

2.2.2.2 Trauma in the periocular area

Eyelid wound and canalicular laceration

The incidence of eyelid lacerations has been 16/100 000 in a cross-sectional study of emergency department visits for ocular trauma in the USA (Ramirez, Porco et al. 2018). Eyelid wounds or canalicular lacerations have accounted for 0.1-8 % of eye injuries treated by ophthalmologists in Scotland and Finland (3 % in sport and 8 % in other patients) (MacEwen, Caroline 1989, Leivo, Puusaari et al. 2007). In emergency department visits, they accounted for 2 % of all eye injuries in the USA (McGwin, Owsley 2005).

Eyelid wounds are often related to other high-energy injuries such as OGT, contusions and orbital fractures (Forbes, Katowitz et al. 2008, Wasfi, Kendrick et al. 2009, Chattopadhyay, Mukhopadhyay et al. 2010, Shoshi, Shoshi et al. 2012, Mishra, A., Baranwal et al. 2013, Tabatabaei, Kasaei et al. 2013, Aytogan, Karadeniz Ugurlu 2017).

Dog bites, blows or punches, sharp objects and falls are common causes of eyelid wounds (Kennedy, R. H., May et al. 1990, Forbes, Katowitz et al. 2008, Aytogan, Karadeniz Ugurlu 2017). Dog bites have an increased risk for canalicular lacerations compared with periocular wounds due to other reasons both when considering all patients (66 % vs. 37 %) and children (36 % vs. 4 %) (Savar, Kirszrot et al. 2008, Sadiq, Corkin et al. 2015).

The lower eyelid is a more common site of trauma than the upper or both eyelids (Kennedy, R. H., May et al. 1990, Ejstrup, Wiencke et al. 2014, Aytogan, Karadeniz Ugurlu 2017).

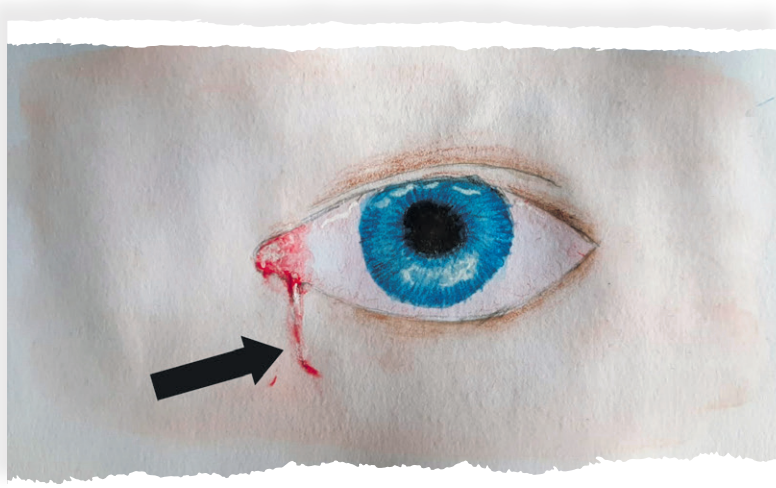


Figure 5. Wound in nasal eyelid (arrow) arouses a suspicion of canalicular laceration.

Intraorbital foreign body

Many case reports have been released on various materials that infiltrated the orbital cavity (Jacobs, Morgan 1988, Asif, Pohchi et al. 2014, Hamilton, Meena et al. 2014, Swathi, MS et al. 2014, Dasgupta, Vats et al. 2015, Erickson, Modi et al. 2015, Bayramoglu, Sayin et al. 2018). In the study performed by Fulcher et al. (2002), metallic foreign bodies were the most common (55 %) cause of injury, followed by organic (33 %) and inorganic (13 %) material (Fulcher, McNab et al. 2002).

In Australia 73 % of patients injured by intraorbital foreign bodies were under 30 years of age (n = 40). The most common causes were shooting (28 %), children playing/falling onto an object (28 %), industrial accidents (23 %) and assault (10 %) (Fulcher, McNab et al. 2002).

Many intraorbital foreign bodies are reported to be found with a delay, even years after an accident. In some cases an infection or tumour has masquerade to be an intraorbital foreign body (Fulcher, McNab et al. 2002, Dasgupta, Vats et al. 2015, Bayramoglu, Sayin et al. 2018).

Other periocular injuries

Periocular injuries have accounted for 22 % of the top 10 eye-related emergency department visits in the USA (Owens, Mutter 2006). Treated by ophthalmologists, 2.5-5 % of all eye injuries involved periocular tissues (MacEwen, Caroline 1989, Leivo, Puusaari et al. 2007). In Finland, periocular bruises accounted for 5 % of all eye injuries in a 6-month period (Leivo, Puusaari et al. 2007). Lid abrasion accounted for 1 % and adnexal contusions 7 % among children in sport-related eye injuries (n = 93) (Hoskin, Yardley et al. 2016).

The incidence of eye burn and adnexa has been 6.5/100 000 in the USA (Ramirez, Porco et al. 2018). Chemical injuries accounted for 3-7 % of eye injuries treated by ophthalmologists (MacEwen, Caroline 1989, E Mönestam, U Björnstig 1991).

2.2.2.3 Traumatic optic neuropathy

The incidence of traumatic optic neuropathy was 1/1 000 000 in the UK and 0.15/100 000 in the USA (Lee, V., Ford et al. 2010, Ramirez, Porco et al. 2018). Traumatic optic neuropathy may be caused by blunt or penetrating trauma to the orbit or described as indirect or direct trauma to the optic nerve (Dworak, Nichols 2014, Chaon, Lee 2015). Head collision predisposes to optic nerve trauma in the bony optic canal (Chaon, Lee 2015).

The main causes in adults were traffic accidents (52 %) and assault (20 %) (Yan, Chen et al. 2017). In children, sports caused 23 %, falls 19 % and traffic accidents 16 % (n = 26) (Ford, Lee et al. 2012). Traffic accidents were also a primary reason (22 %) followed by firearms (16 %) in a study concerning the injuries of visual pathways (n = 970), 86 % of which were optic nerve traumas (Gise, Truong et al. 2018). Traumatic optic neuropathy resulting from toy gun trauma is rare but paintball has come up in reports (Thach, Ward et al. 1999).

2.2.2.4 Orbital fracture

The incidence of orbital floor fracture was 9/100 000 in the USA (Ramirez, Porco et al. 2018). Orbital fractures accounted for 0.1-2 % of all eye injuries in Finland and Scotland (MacEwen, Caroline 1989, Leivo, Puusaari et al. 2007).

Among children, falls, hits from balls and assault form a common cause (50 %) for orbital fractures (Miller, Elman et al. 2018). In Australia, orbital fractures comprised 29 % of sports-related eye injuries in children. Collision was the main reason (76 %) (Hoskin, Yardley et al. 2016).

Regarding sports-related eye injuries, orbital fractures have accounted for 1-2 % (Ghosh, Bauer 1995, Filipe, Barros et al. 1997, Leivo, Puusaari et al. 2007). Among patients treated in the emergency department as a result of a sport eye injury, 9.5 % had orbital fractures (Haring, Sheffield, Canner et al. 2016).

2.3 SEVERITY OF THE EYE TRAUMA

2.3.1 OCULAR TRAUMA SCORE

The Ocular trauma score (OTS) has been created to help ophthalmologists evaluate the severity and prognosis of the expected outcome after serious eye injury in the early stages. To find the anatomic and physiologic variables that affect the recovery, over 2500 eye injury studies were analysed based on the standardized terminology system in Hungary and the USA performed by Kuhn et al. (2002). The variables are listed in Table 8, the calculation method in Table 9 and the conversion to OTS-points in Table 10. Small scores in OTS indicate a worse visual prognosis (Table 10) (Pieramici, Sternberg et al. 1997, Kuhn, Ferenc, Maisiak et al. 2002). OTS has proved to be in accordance in many studies (Court, Lu et al. 2019)

Table 8. Classification of the variables used in OTS.

Visual acuity	≥ 0.5
	0.2 - 0.4
	0.005 - 0.1
	Light perception/hand movement
	No light perception
Pupil	RAPD present in affected eye
	RAPD absent in affected eye
Closed globe injury	Contusion
	Lamellar laceration
	Superficial foreign body
	Mixed
Open globe injury	Rupture
	Penetrating
	Intraocular foreign body
	Perforating
	Mixed

RAPD = Relative afferent pupillary defect

Table 9. Raw points of visual acuity are first estimated. Then, the points given to each variable are subtracted. Only existing variables are taken into account.

Variables	Raw points
Visual acuity	
≥ 0.5	100
0.2 - 0.4	90
0.005-0.1	80
Light perception/hand movement	70
No light perception	60
Rupture	-23
Endophthalmitis	-17
Perforating injury	-14
Retinal detachment	-11
Relative afferent pupillary defect	-10

Table 10. Converting raw points to OTS and probability of final visual acuity compared to OTS-points.

Raw points	OTS	NLP	LP/HM	0.005-0.1	0.2-0.4	≥ 0.5
0-44	1	74 %	15 %	7 %	3 %	1 %
45-65	2	27 %	26 %	18 %	15 %	15 %
66-80	3	2 %	11 %	15 %	31 %	41 %
81-91	4	1 %	2 %	3 %	22 %	73 %
92-100	5	0 %	1 %	1 %	5 %	94 %

OTS = Ocular trauma score
NLP = No light perception
LP/HM = Light perception/hand movement

2.3.1.1 Ocular Trauma Score in paediatric patients

The predictive accuracy of OTS in paediatric patients may be difficult to evaluate. In children, VA and relative afferent pupillary defect (RAPD) may be difficult to determine, and post-operative inflammation, scarring and proliferative vitreoretinopathy may be more extensive compared with adults. All of these may cause amblyopia and may affect the anatomic and functional outcomes (Unver, Kapran et al. 2009, Acar, Tok et al. 2011, Shah, Shah et al. 2012). Still, OTS has had reliable prognostic value in several studies (Uysal, Mutlu et al. 2008, Shah, Shah et al. 2012, Hossain, Hussain et al. 2014, Schörkhuber, Wackernagel et al. 2014, Zhu, Wu et al. 2015). Patients in the studies performed by Hossain et al. (2014) and Uysal et al. (2008) lacked children under the age of 3 years.

Acar et al. (2011) used the Paediatric Ocular Trauma Score (POTS) to represent penetrating ocular traumas in paediatric patients, in which the initial VA and RAPD were not evaluated. Instead, the age of the patient, anatomic location of the wound and concomitant eye pathology (iris prolapse, hyphema, organic or unclear injury, delay of surgery, traumatic cataract and vitreous haemorrhage) were taken into account. In the study by Zhu et al. (2015), POTS was reliable in penetrating eye injuries, but OTS was used in traumatic cataract following penetrating eye injury (Zhu, Wu et al. 2015). OTS is considered to be as reliable as POTS in the study by Schörkhuber et al. (2014).

2.3.2 ZONES OF INJURY

The location of injury influences the prognosis of the final visual acuity after eye injury. The location of the injury can be described by zones, which are introduced in Table 11. In perforations and in multiple penetrating traumas, the most posterior location is chosen as a defect site. In case of IOFB, the location is the entry site. More posterior (zone III) injuries tend to have a worse prognosis than more anterior (zone I) injuries (Pieramici, Sternberg et al. 1997, Fujikawa, Mohamed et al. 2018).

Table 11. Zones of injuries in closed and open globe trauma.

Zone	Closed globe trauma From surface to deeper structures	Open globe trauma From anterior to posterior structures
Zone 1	Cornea, conjunctiva, sclera	Cornea, including limbus.
Zone 2	Anterior segment to the posterior lens capsule (anterior chamber, iris, lens, pars plicata 2mm from limbus)	Sclera 5mm posterior from limbus
Zone 3	Posterior segment (ciliary body, choroid, vitreous, retina, optic nerve)	Posterior sclera > 5mm from limbus

A simple way to illustrate the eye in closed globe traumas is as peeling an onion and in open globe traumas as slicing an onion into rings (Figure 6).

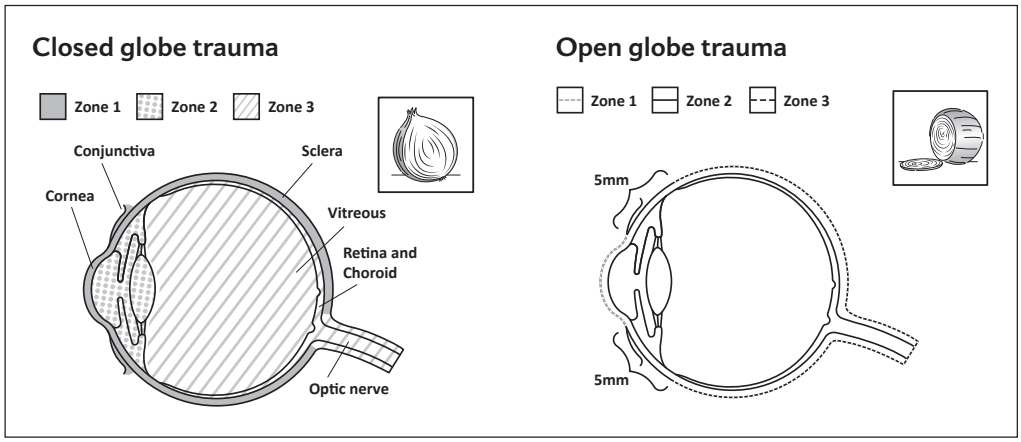


Figure 6. In closed globe traumas injury site is categorised from outer to inner segments (cf. peeling an onion). In closed globe trauma injury site is from anterior to posterior site (cf. slicing an onion).

2.3.3 TRAUMATIC GLAUCOMA

If glaucoma is associated with previous trauma, it is called traumatic glaucoma. In India, it accounted for 11-13 % of all new secondary glaucoma cases in the 1990's and 2000's. Traumatic glaucoma was found more frequently in patients under the age of 30 than in those older than 30 (36 % vs. 1.3 %) (Sihota, Sood et al. 1995). Of all trauma-associated glaucoma cases, 71 % were found in patients under 30, mean age was 26 and blunt ocular trauma was the leading cause (87 %) (Gadia, Sihota et al. 2008).

Vitreous haemorrhage or corneal injury increase the risk for glaucoma. After open globe trauma, the risk for glaucoma surgery is higher compared with blunt ocular trauma (58 % vs. 12 %). After blunt ocular trauma, surgery is often needed earlier (less than 6 months after trauma) than after open globe trauma. (Ozer, Yalvac et al. 2007)

Glaucoma may present itself years after eye trauma. The diagnosis of traumatic glaucoma was made less than a month in 31 %, within a year in 25 % and over 20 years after the trauma in 8 % (n = 100) (Sihota, Sood et al. 1995). Traumatic glaucoma was found 4 to 10 years after trauma in studies by Lee et al. (2017) and Kaufman and Tolpin (1974).

Traumatic glaucoma after closed globe trauma

The glaucoma risk after blunt ocular trauma has been evaluated to be 3 % in six months in a large cohort study of 6021 patients in the USA. The risk factors were poor initial visual acuity, advancing age, lens injury, angle recession and hyphema (Girkin, C. A., McGwin et al. 2005).

Strong correlation has been found between traumatic glaucoma after blunt ocular trauma and traumatic cataract, angle recession of more than 180°, significant iris damage and displacement of the lens. Two of these four findings were present in all traumatic glaucoma cases (Sihota, Sood et al. 1995).

Angle recession (180° degrees or more in 87 % of cases) was observed in 66 % of Indian patients diagnosed with traumatic glaucoma. Sphincter tears, hyphema, iridodialysis, subluxation or dislocation of lens, vitreous haemorrhage, retinal detachment and traumatic cataracts were seen in 95 % of cases (Gadia, Sihota et al. 2008).

Traumatic glaucoma after open globe trauma

The incidence of traumatic glaucoma has been reported to be from 3 % according to a large cohort study of 3627 patients in the USA (follow-up 6 months) to 5 % in 775 patients in Saudi-Arabia (follow-up 3 months - 14 years) (Girkin, Christopher A., McGwin et al. 2005, Osman 2015).

The reason for traumatic glaucoma after OGT may be mechanical damage of eye tissue or inflammation such as anterior synechiae, a pupillary block or a trabeculitis (Jones 1987).

Risk for traumatic glaucoma increases with advancing age, lens injury (lenticular damage or displacement of the lens), adherent leucoma, poor baseline VA, inflammation, IOFB, vitreous haemorrhage and with perforation rather than penetration (Jones 1987, Sihota, Sood et al. 1995, Girkin, Christopher A., McGwin et al. 2005, Osman 2015). Phacoanaphylaxis, angle recession, and siderosis are also considered as the risk factors (Bai, Yao et al. 2009). Penetrating ocular trauma increases the need for glaucoma surgery (Ozer, Yalvac et al. 2007).

Traumatic glaucoma after chemical eye injury

Severe ocular chemical burns increase the risk for glaucoma (Lin, Esioglu et al. 2012). The suspected mechanism is the shrinkage of the eye tissue due to direct injury, which may cause damage to the trabecular meshwork and inhibit the outflow (Paterson, Pfister 1974). The elevation of the eye pressure is observed more than 24 hours after the eye injury in animal tests (Paschalis, Zhou et al. 2017). Also, inflammation as well as long term use of

corticosteroids may increase the risk for glaucoma in these cases (J P Kersey, D C Broadway 2006, Weinreb, Aung et al. 2014).

2.4 RESOURCE USE

Eye injuries pose substantial costs to society. WHO concluded, that though eye injuries are often monocular injuries, they occur frequently, especially in the active years of life. Frequent follow-up visits mean loss of working capacity and loss of income. In the most severe cases, rehabilitation and special education services are also among the main concerns (Négrel, Thylefors 1998). Costs include health care (direct health care costs e.g. outpatient visits in the hospital, surgery, in-patient days and medication), non-health care costs (travel, home care and patient aid) and time costs (lost productivity). The costs include lifelong costs caused by the injury.

There is limited data on the costs of eye injuries, and indirect measures, such as the number of resources used, are often reported. Previous studies have mainly reported on the need for hospitalization, which is an indirect measure of one major health care cost component.

In industrialized countries, the estimated incidence of eye injury that requires hospitalization is estimated to be 13/100 000 population per year and therefore concerns 750 000 patients worldwide. The incidence of eye injuries that need medical attention is estimated to be 1000/100 000 population per year. The incidence of eye injuries causing activity restriction for more than one day is estimated to be 950/100 000 population per year and therefore concerns 55 million patients worldwide each year (Négrel, Thylefors 1998).

In the eye emergency department, patients with a trauma diagnosis are more likely to be hospitalized compared with non-trauma patients (Fong 1995, Channa, Zafar et al. 2016). Hospitalization was needed for 20 % of eye injury patients, more so for older patients (age 70-80 years) than younger (less than 70 years) (50 % vs. 16-17 %), in a study in which 3353 people over 40 years of age were interviewed (Wong, Man et al. 2018).

The most common diagnoses leading to hospitalization have been OGT (47 %), adnexal wound (20 %), orbital fracture (11 %) and hyphema (11 %) (Baker, Wilson et al. 1999). In a study by Ghosh and Bauer (1995), 13 % (36/272) of contusion-patients were admitted to the hospital (Ghosh, Bauer 1995). The duration of hospitalization was 10 (5-13) days for children in Croatia (n = 353) (Bućan, Matas et al. 2017).

2.5 PREVENTION OF EYE INJURIES

It has been estimated that 90 % of eye injuries would be avoidable through correct usage of eye protection and eye safety practices (Pizzarello 1998, Négrel, Thylefors 1998). In the USA, the reduction of eye injuries from 477 to 212/100 000 between the years 1993 and 2011 was explained by stricter eye protection regulations in the workplace, awareness campaigns and increased use of seatbelts (Channa, Zafar et al. 2016).

Eye protection in children

Children's eye injuries often occur at home, as highlighted by Philip and Hoskin, who em-

phasised a safe environment at home (chemicals out of reach, age-suitable toys, no sharp edges) and the importance of supervision of children's activities (Podbielski, Surkont et al. 2009, Pollard, Xiang et al. 2012, Philip, Hoskin 2014, Yardley, Hoskin et al. 2017).

In children, the use of eye protection has been observed as low. Most eye protection standards are aimed at adults, but it is also a standard for children in several sports such as youth baseball and children's motocross in Australia. Eye protection designed for adults is not necessarily suitable for children. The example and attitude of parents and coaches are essential for educating children about eye protection (Dain 2016, Hoskin, Philip et al. 2016).

In a review article, Hoskin et al. (2016) concluded that policies and legislation, education and personal eye protection are among the ways to influence children's eye protection.

Eye protection in toy gun games

The use of protective facemasks in paintball and airsoft is obligatory and regulated by the European Paintball Federation, European Airsoft Association, and by the Finnish Paintball Federation (Finnish Paintball Federation, European Paintball Federation, United Kingdom Airsoft Players Union). The facemasks must meet the requirements of the American Society of Testing and Materials: ASTM F1776 for paintball and ASTM F2879173 for airsoft (Table 12).

Table 12. Standards for some sports and activities.

Reason for eye protection	Sport/activity	Standard
High-speed projectiles	Paintball	ASTM F1776172
	Airsoft	ASTM F2879173, banned in Australia
Racquet sport	Squash	ASTM F803, AS/NZS 4066, CSA P400
	Tennis	ASTM F803, AS/NZS 4066
	Badminton	ASTM F803, AS/NZS 4066
Bat and ball sport	Baseball	
	Lacrosse	ASTM F803, CSA Z262.8174
	Ice Hockey	ISO 10256193, EN ISO 10256, CSA Z262.2194, ASTM F513195NOCSAE 035-11m12189, 196b
	Ice hockey, goaltender	ISO 10256, EN ISO 10256, CSA Z262.2, ASTM F1587197
	Ringette	CSA Z262.5198
	Martial Arts	EN 13277201
Environmental hazard	Skiing	EN 174202
	Snow-boarding	EN 174
	Swimming goggles	JIS S 7301205
Other	Firework	EN 166

AS/NZM = Standards Australia and Standards New Zealand
ASTM = American Society of Testing and Materials
CSA = Canadian Standards Association
ISO = International Organization for Standardization
EN = European Standard
NOCSAE = National Operating Committee on Standards for Athletic Equipment
JIS = Japanese Industrial Standards

Contrary to the rules of the games, the use of eye protection is often abandoned. In Table 13, the compliance of the use of eye protection in the studies concerning toy gun games can be seen. Fineman et al. (2000) reported that eye protection was removed mainly because of fogging and paint splatter.

Table 13. Misuse of eye protection in toy gun games.

Author, year	Country	N	Type of game	Eye protection		
				Not used % (n)	Removed % (n)	Inappropriate glasses % (n)
Thach et al. (1999)	USA	13	Paintball	31 % (4)	54 % (7)	NA
Kitchen et al. (1999)	USA	11	Paintball	NA	NA	18 % (2)
Fineman et al. (2000)	USA	35	Paintball	40 % (14)	51 % (18)	NA
Saunte and Saunte (2006)	Denmark	33	Airsoft	100 % (33)	NA	NA

NA = Data not available

Eye protection in sports

In sports, the primary function of the standards for eye protection is to provide adequate protection against hazards of the sport (Dain 2016). Dain (2016) outlined a three-step hierarchy in managing the risk of hazards to the eye in sports: first, the risk must be accepted when choosing the sport; secondly, one must obey the rules; and thirdly, personal eye protection must be used. Table 12 shows some sports which have standards for eye protection.

In sports, the effectiveness of eye protection has been proven in many studies. The results of ice hockey in Canada were the pioneers in this endeavour. The use of standardized eye-protection diminished eye injuries from 253 to 42 and legal blindness from 37 to 12 between 1974-75 to 1978-79 (Pashby, Pashby et al. 1975, Pashby 1979). In women's lacrosse, eye injuries diminished from 0.1/1000 to 0.016/1000 per year by mandatory use of protective eyewear in the USA (Lincoln, Caswell et al. 2012). In Sweden, a recent study showed that eye injuries among young floorball players were rare after the use of eye protection. Most eye injuries took place during non-licensed games (Bro, Ghosh 2017).

Eye protection from wooden projectiles

The Centre for Occupational Safety has released instructions for safe work practices in forestry and use of a saw in Finland, which includes the use of a helmet and a visor (The Centre for Occupational Safety). In wood industry, the safety regulations include the use of protective eye wear and instructions to ensure the cleanliness and soundness of glasses (Kuusisto, Varpula et al. 2005).

3 AIMS OF THE STUDY

I. To determine the current population-based epidemiology of sportrelated eye injuries, the use of resources, treatments and outcome of these injuries and give up-to-date evidence-based recommendations for the use of protective eyewear in sports.

II. To determine the current population-based epidemiology of children's eye injuries, causes and consequences by analysing findings, treatment, use of resources and outcomes of these injuries.

III. To present the current population-based epidemiology, findings, treatment, long-term outcome and use of resources for eye injuries caused by toy guns.

IV. To present the current population-based epidemiology, findings, treatment and use of resources for eye injuries caused by branches, sticks and other wooden materials.

4 PATIENTS AND METHODS

4.1 STUDY DESIGN

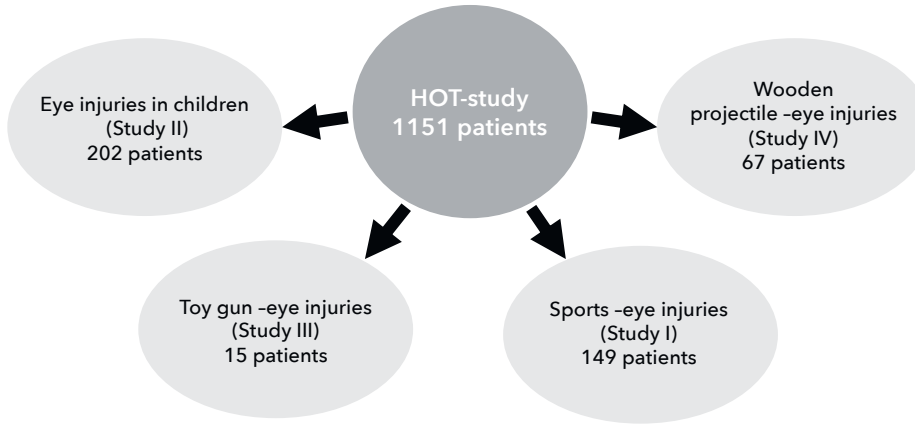
The study analysed patients who have suffered an eye injury and were aged 16 or under (Study II), the eye injury was caused by a toy gun (Study III), by a sport activity (Study I) or by a wooden projectile (Study IV), and who were treated at the Helsinki University Eye Hospital (HUEH) during a one-year period between 1st of May 2011 and 30th of April 2012. This study is a part of the Helsinki Ocular Trauma (HOT) Study, which included all patients treated for eye injuries in HUEH during one year (n = 1151). The information on study groups can be found in Figure 7.

HUEH is a tertiary and secondary eye care hospital in Helsinki, the capital of Finland. The population base of HUEH is 1.5 million and is responsible for both urban and rural areas in Southern Finland; it is the primary eye hospital for almost a third of the Finnish population of 5.4 million.

The data was collected by MD Anna-Kaisa Haavisto, MD Ahmad Sahraravand and MD Tiina Leivo. The patients were prospectively determined in the emergency clinic and retrospectively from hospital records by verifying the ICD-10 diagnoses directly or indirectly indicating eye injury. Patients admitted for suspected or known trauma without any clinical findings were excluded.

The study was approved by the ethics committee of the Helsinki-Uusimaa Hospital district and followed the tenets of the Declaration of Helsinki. Informed consent was obtained from all patients and, in cases of children, from their parents.

Figure 7. Patients included to this thesis in Studies I-IV are part of the Helsinki Ocular Trauma (HOT) study.



4.1.1 IDENTIFYING PATIENTS INCLUDED IN THE STUDY

In order to find eligible patients that were missed in the prospective identification, hospital records were accessed. Then, ICD-10 (International classification of diagnosis, tenth revision) diagnoses beginning with T or S were gathered. Diagnoses that are often related to trauma in clinical practice were verified and are shown in Table 14.

Table 14. Incorrectly used non-trauma diagnoses in trauma patients

ICD-10 diagnose	Diagnose in English
H04.0	Dacryoadenitis
H10.3	Acute conjunctivitis
H11.4	Other conjunctival vascular disorder and cyst
H16.0	Corneal ulcer
H16.2	Keratoconjunctivitis
H16.9	Keratitis
H20.0	Acute or subacute iridocyclitis
H21.0	Hyphema
H33.0	Retinal ablation with retinal break
H33.3	Retinal break without detachment
H35.8	Retinal oedema
H43.1	Vitreous haemorrhage
H43.3	Other vitreous opacity
H43.8	Other disorder of vitreous body
H47.0	Disorder of optic nerve

4.2 PATIENTS

4.2.1 EYE INJURIES IN CHILDREN (STUDY II)

The study group included patients aged 16 or younger and treated for eye injuries. Shaken baby patients were not included, since they are initially treated in a children's hospital and could not be traced reliably.

4.2.2 EYE INJURIES CAUSED BY TOY GUNS (STUDY III)

The study group included patients injured by toy guns: airsoft guns, paintball guns and pea-shooters. Real guns or weapons were excluded.

4.2.3 EYE INJURIES CAUSED BY SPORTS (STUDY I)

The study group included patients injured during a sport activity or related sport equipment. Airsoft injuries were not included.

4.2.4 EYE INJURIES CAUSED BY WOODEN PROJECTILES (STUDY IV)

The study group included patients injured by wooden sticks and branches. Wooden dust, cosmetic wooden items and matchsticks were excluded.

4.3 METHODS

4.3.1 FOLLOW-UP TIME

The follow-up time was 3 months or until the last visit. In Study III, patients were also examined 5-6 years after the eye injury.

4.3.2 QUESTIONNAIRE ON THE INCIDENT

Patients were prospectively identified in the emergency clinic and were given a questionnaire to fill out. The questionnaire dealt with detailed information about the traumatic event and the circumstances: the date, time and place of the accident, trauma object and activity, relation to work, use of protective eyewear, influence of alcohol and intentionality. In case of children (Study II), the questionnaire was filled out by the caregivers.

In case of a sport-related eye injury (Study I), the questionnaire also included questions on previous sport eye trauma experienced by themselves or a sportmate, the current use and willingness to use protective eyewear in the future. A self-assessment of the potential degree of danger of their sport to the eyes was also inquired. In the absence of the question-

naire, the information was gathered from hospital records.

The year was divided into four seasons: spring (March, April, May), summer (June, July, August), autumn (September, October, November) and winter (December, January, February) because some trauma-causing activities in Finland are seasonal.

4.3.3 CLINICAL NOTES

Thorough clinical findings were gathered from hospital records, including diagnoses, anatomic location of the injury, medication, surgeries, the number of outpatient visits and hospitalization days, sick leave days and sports restriction. During the initial visit, the most significant finding for each anatomical location was reported. At the time of the last visit, the final visual acuity, the IOP and the main abnormal status findings were recorded.

4.3.4 EXAMINATION OF PATIENTS (STUDY III)

In Study III (Toy gun eye injuries), an additional thorough eye examination was performed five years after the accident by the dissertation researcher Haavisto. The examination included evaluation of best corrected visual acuity, IOP (Goldmann applanation tonometry) or in case of lack of co-operation with Icare (Icare TAOi, Icare Finland Oy, Vantaa, Finland), gonioscopy, slit lamp biomicroscopy and dilated fundus examination. All patients underwent a visual field (VF) examination by the Octopus G dynamic program (Haag-Streit AG, Bern, Switzerland) or Goldmann in case of lack of co-operation. The peripapillary nerve fibre layer (NFL) thickness was measured using optical coherence tomography (OCT) (Heidelberg Engineering, Heidelberg, Germany). Stereo disc photographs and fundus NFL photographs were taken (Canon Digital CX-1, Canon, Tokyo, Japan). The severity was also defined by asking the patients about their subjective symptoms in eyes and vision.

4.3.5 CLASSIFICATION BY BETTS AND DIAGNOSIS GROUPS

The eye injuries were categorized according to BETTS. The diagnoses were divided into six groups based on the primary diagnosis. The groups are shown in Table 15. These categories were created, since many adnexal eye traumas treated by the ophthalmologist cannot be categorized according to BETTS.

In case of multiple diagnoses, the primary diagnosis was the diagnosis that was the most significant or needed the most healthcare resources, other diagnoses were secondary. If both eyes were injured, the more seriously injured eye was observed.

Table 15. Diagnosis groups of the study, affiliated ICD-10 codes and category according to BETTS.

Diagnosis group	ICD-10 diagnosis	BETTS category
Contusion	S05.1	Closed globe
Open globe trauma	S05.2, S05.4, S05.5, S05.6	Open globe
Lid or lacrimal wound	S01.1, S01.0, S01.8, S01.9	-
Orbital fracture	S02.3	-
Chemical or thermal burn injury	T26.1, T26.4, T26.6	-
Other mild orbital or periorbital injury	S00.1, S00.2, S05.0, T15.0, T15.1	-

4.3.6 THE USE OF RESOURCES

The resource use was estimated according to the number of outpatient visits, the duration of hospitalizations, use and duration of medication, the number of operations performed and the number of needed general anaesthesia. The need for sick leave days was analysed in Study I (Sports eye injuries) and in Study III (Toy gun eye injuries). Sport restrictions were analysed in Study I. If sick leave or activity restriction was not recorded, their need was estimated based on clinical findings and international recommendations (Recchia, Saluja et al. 2002, Gerstenblith, Rabinowitz 2009, Tsai, Denniston et al. 2011).

4.3.7 FACTORS FOR EVALUATING THE SEVERITY OF THE EYE INJURY

The severity of the eye trauma was evaluated using an OTS rating in Study I (Sports eye injuries) and II (Eye injuries in children). The amount of surgeries performed as well as the need for surgery in the future was estimated. The need for lifelong follow-up was also estimated. Permanent disability was estimated, if the patient had abnormal VA or other functional symptoms: glare, diplopia, lack of accommodation in case of children or lowered quality of central vision.

4.3.8 ACTIVITY CATEGORIES IN EYE INJURIES CAUSED BY WOODEN PROJECTILES (STUDY IV)

The activity during the accident was categorized and divided into gardening, play, woodwork, forest work, outdoor recreation or sport, if possible. Woodwork meant working with wood as a hobby or vocation. Forest work was picked, when the trauma occurred during silviculture work, e.g. harvesting wood and planting. Children aged 10 and under were not included for analysis due to lacking data. The energy of the trauma was evaluated as high, if tools or falling was involved.

4.3.9 DATA ANALYSIS AND STATISTICAL METHODS

Studies I, II, III and IV

The epidemiological factors, clinical findings, treatments, use of resources and outcome data were analysed and categorized. If the proportion of unavailable data was over 10 %, the number of missing cases was reported.

The absolute and relative frequencies were represented (Excel, Microsoft Office 2013, Microsoft, Redmont, WA). The relationship between different categorized variables was presented using crosstables. The diagnosis groups were crosstabled by causes and activity.

The yearly incidence of eye injuries for different age groups was calculated. The incidence was calculated from the estimated average population living in the HUEH district in 2011-2012 (1 536 657) (Statistics Finland, cited 1.2.2016) to be the population at risk.

Use of different health care resources, sick leave and physical activity restrictions were represented by the number of involved patients, the mean and range per patient involved and total number of resource units used.

Study I

The yearly incidence of eye injuries per 1000 participants in different sports was compared by determining the proportion of injuries relative to the estimated number of participants in the sport in the area of HUEH. The estimated number of participants was calculated by dividing the participant population in the national fitness study in 2009–2010 (Nuori Suomi, SLU et al. 2010) by the population proportion in the HUEH district in 2011. The incidence rate confidence intervals were calculated by the Exact method. Age distribution and ICD-10-based primary diagnoses related to sports were calculated.

The yearly ocular injury incidence for different sports was compared between the current 2011–12 data and 2002–03 data. As the latter data (Leivo, Puusaari et al. 2007) was collected for a 6-month period, and many sports are to some extent seasonal, the comparison was performed for an equal, 6-month time period of 3.12.2011–3.6.2012. Confidence intervals of 95 % and a chi-square distribution test were used for statistical analysis of incidence rate differences.

The four biggest eye injury causing sports were statistically analysed, comparing the sport where the proportion of permanent impairment was highest to all other sports combined by Fisher's exact test.

Study IV

The incidence of eye injuries in each activity was calculated by dividing the number of accidents by the time spent in each activity. 95 % confidence intervals were used for statistical analysis of the incidence rate differences of the following activities: gardening, woodwork, forest work, outdoor recreation and sport. Data were available for patients aged 10 or older (Saastamoinen, Vaara 2009, Statistics Finland PX-web statistical database). Play was not analysed, since 12 out of 18 patients injured during playing were younger than 10.

5 RESULTS

The structure of the study groups and the percentage of respondents in each study group can be seen in Table 16.

Table 16. Information about the number of patients, age, gender and follow-up time in research groups.

Type of eye injury	Study	N	Percentage of all (n=1051) patients	Mean age (range), [y = years]	Children (age ≤ 16) % (n)	Males	Respondents to the questionnaire % (n)	Follow-up time
Eye injuries in children	II	202	18 %	9 y (6 weeks - 16 y)	100 % (202)	74 %	55 % (112)	3 mos
Toy gun eye injuries	III	15	1 %	15 y (3-47 y)	80 % (12)	93 %	67 % (10)	5 years
Sports eye injuries	I	149	13 %	33 y (6-82 y)	26 % (38)	81 %	72 % (108)	3 mos
Wooden projectile eye injuries	IV	67	6 %	42 y (3-87 y)	22 % (15)	76 %	58 % (39)	3 mos

Mos. = Months

5.1 EYE INJURIES IN CHILDREN (STUDY II)

The study comprised 202 patients (149 males and 53 females). The incidence was from 5/10 000 in the age group of 0-6 years to 8/10 000 in the age group of 13-16 years. The mean age was 9 years (range 6 weeks–16 years). The majority of the eye injuries occurred in 13- to 16-year-olds. Nine patients were lost to follow-up.

The most common causes of eye injuries were sports equipment (15 %; n = 31), contact with the human body (12 %; n = 25) and superficial foreign bodies (11 %; n = 22). The causes in relation to the primary diagnoses can be seen in Table 17. More eye injuries occurred in spring and autumn (29 and 27 %, respectively) than in winter (22 %) and summer (22 %).

Protective eyewear was used by three patients; each of whom were injured by fireworks, a toy gun or welding, respectively.

The most common diagnosis group was minor eye injuries (50 %; n = 101), including corneal abrasion or superficial foreign body, superficial contusion in eyelid or in the peri-ocular area. The other major diagnosis was contusion (30 %; n = 60) followed by wounds (9 %; n = 18), chemicals and burns (6 %; n = 13), open globe injuries (3 %; n = 6) and orbital fractures (2 %; n = 4). Open globe traumas were caused by fireworks (n = 2), tools (n =2), a ski pole (n = 1) and a gun (n = 1).

The number of outpatient visits was 443 and hospitalization days 49. Medication was needed for 88 % (n = 177) of patients. Activity restriction was assigned for 72 % (n = 145) of

patients. Overall surgery was needed for 23 % (n = 46) of patients, and the need for future surgery was assumed for six patients.

Permanent disability was estimated for 9 % (n = 19) of patients. The need for lifelong follow-up was estimated for 29 % (n = 58) of patients diagnosed with contusion and open globe trauma.

Table 17. Causes, major surgeries, permanent disability and need for lifelong follow-up by primary diagnosis group.

Cause	ALL	Contusion	Wound	Chemical	OGT	Orbital tr.	Other[1)]	Major surgeries	Permanent disability	Need for lifelong follow-up
Sports equipment	31 (15 %)	24	1	-	1	-	5	4 (13 %)	3 (10 %)	21 (68 %)
Body part	25 (12 %)	4	1	-	-	3	17	4 (16 %)	4 (16 %)	1 (4 %)
Superficial FB	22 (11 %)	-	-	-	-	-	22	-	-	-
Toys	16 (8 %)	2	1	-	-	-	13	1 (6 %)	1 (6 %)	2 (13 %)
Sticks	15 (7 %)	6	2	-	-	-	7	1 (7 %)	-	6 (40 %)
Pellet guns	12 (6 %)	10	-	-	-	-	2	2 (17 %)	4 (33 %)	10 (83 %)
Chemicals	8 (4 %)	-	-	8	-	-	-	-	-	-
Animals	7 (3 %)	-	4	-	-	-	3	3 (43 %)	-	-
Fireworks	4 (2 %)	1	-	1	2	-	-	3 (75 %)	3 (75 %)	3 (75 %)
Pens/pencils	4 (2 %)	-	1	-	-	-	3	1 (25 %)	-	-
Thermal injury	4 (2 %)	-	-	4	-	-	-	-	-	-
Tools	3 (1 %)	-	-	-	2	-	1	2 (67 %)	2 (67 %)	2 (67 %)
Gun	1 (<1 %)	-	-	-	1	-	-	1 (100 %)	1 (100 %)	1 (100 %)
Other	50 (25 %)	13	8	-	-	1	28	6 (12 %)	1 (2 %)	12 (24 %)
Total	202	60 (30 %)	18 (9 %)	13 (6 %)	6 (3 %)	4 (2 %)	101 (50 %)	28 (14 %)	19 (9 %)	58 (29 %)

OGT = Open globe trauma
Orbital tr. = Orbital trauma
Superficial FB = Superficial foreign body
[1)] Other mild orbital or periorbital injury

5.2 EYE INJURIES CAUSED BY TOY GUNS (STUDY III)

The study comprised 15 patients (14 males and 1 female). The mean age was 15 years. The incidence was 1.0/100 000 for all toy guns and 0.8/100 000 for airsoft toy guns. 13 patients were re-examined after five to six years of the initial eye injury. One patient was lost to follow-up, and another patient was only interviewed by telephone after five years.

The injuries were caused by airsoft guns (80 %; n = 12), pea shooters (13 %; n = 2) and paintball guns (7 %; n = 1).

Protective eyewear was used by four (27 %) patients. The accidents took place after the game (n = 2), while cleaning the glasses (n = 1), and when wrong-sized glasses fell off (n = 1). Two patients were bystanders.

The initial diagnosis was contusion in 13 patients and mild superficial trauma in two patients. The most significant findings were hyphema (n = 13), posterior findings (n = 7), irideal trauma (n = 2) and traumatic cataract (n = 1).

By the end of a 3-month follow-up time, four surgeries were performed on three patients: three for traumatic cataract (including one posterior capsule removal) and one for a retinal tear. One patient had re-bleeding in the anterior chamber and was treated with tranexamic acid. All had normal IOP.

By the end of a 5-year follow-up, eight patients had abnormal findings: irideal trauma (n = 3), intraocular lens (IOL) due to traumatic cataract (n = 3), pigment in vitreous (n = 2), posterior opacity (n = 2), retinal plomb (n = 1) and mydriasis (n = 1). VA was 0.9 Snellen equivalent or better in all except one case, with only light perception without any clinical findings. Further, three surgeries were performed: one cataract surgery, one retinal plomb insertion and one posterior capsular opacity removal.

By the end of the 5-year follow-up, the number of outpatient visits was 90 and hospitalization days 1.

Permanent disability occurred in 47 % (n = 7) of patients due to pain (n = 4), blurred vision (n = 2), lowered VA (n = 1) and glare (n = 1). Glaucoma was not found in any patient, and IOP was normal (< 22 mmHg) in all cases. The need for lifelong follow-up was estimated for 87 % (n = 13) of patients due to contusion.

Table 18. Significant status findings during the first visit and in the 5-year follow-up. Patient number 5 was interviewed by telephone.

Type of toy gun	Age	BCVA		Initial findings			5-year follow-up	
		Initial	*5 y*	*IOP*	*Dg*	*Abnormal findings*	*Abnormal findings*	*Subjective impairment*
Airsoft								
	11	0.1	1.1	17	Contusion	Iridodialysis	Iridodialysis	-
	9	0.63	1.4	14	Abrasion	-	-	-
	10	0.7	1.1	9	Contusion	Macular oedema	-	-
	3*	NA	1.0	17	Contusion	Retinal tear	Retinal plomb	Pain
	47	0.5	NA	14	Contusion	Berlin oedema	NA	Blur
	9	0.05	0.9	17	Contusion	-	IOL, pigment in vitreous	Pain
	14	0.4	1.5	7	Contusion	Iridodialysis, retinal bleeding and oedema	Iridodialysis, pigment in vitreous	Pain
	9	CF	1.0	21	Contusion	Traumatic cataract	IOL, PCO	Blur
	14	CF	1.25	21	Contusion	-	-	-
	12	0.4	1.25	14	Abrasion	-	-	-
	11	0.4	1.1	22	Contusion	Berlin oedema	IOL, sphincter rupture	-
	21	0.1	LP	16	Contusion	Macular oedema, vitreous bleeding	Mydriasis	Low VA, glare, pain
Pea shooter								
	11	0.8	NA	32	Contusion	-	NA	NA
	8	1.0	1.5	12	Contusion	-	-	-
Paintball								
	32	0.6	1.0	18	Contusion	Berlin oedema	Tears in iris	Focus

BCVA = Best corrected visual acuity
y = Year
IOP = Intraocular pressure
Dg = Diagnosis
NA = Data not available
IOL = Intraocular lens
CF = Counting fingers
PCO = Posterior capsule opacity
LP = Light perception
*=Female

5.3 EYE INJURIES CAUSED BY SPORTS (STUDY I)

The study comprised 149 patients (121 males and 28 females). The incidence was 9.7/100 000. The mean age was 33 years (range 6–82 years). The majority of the eye injuries occurred in 10-19-year-olds, but in floorball, the eye injury was most common at 40-49 years of age. Nine patients were lost to follow-up.

The most common eye-injury-causing sports were floorball (32 %; n = 47), football (13 %; n = 19) and tennis (10 %; n = 15). In relation to participants, the most dangerous sports were rink bandy, floorball and tennis. Injuries were caused by sports equipment in 79 %, body parts in 12 % and various other in 9% of cases.

Protective eyewear was used by seven (5 %) patients: four in ice-hockey, two in floorball, one in Formula 1 Powerboating.

The primary diagnoses in each sport are shown in Table 19. Contusion was the most common diagnosis (77 %, n = 114), followed by superficial bulbar or periorbital trauma (14 %; n = 21) and wound (5 %; n = 7). Clinically significant secondary diagnoses occurred in 49 (33 %) patients, including retinal and choroidal tears (n = 11), retinal and vitreous haemorrhage (n = 15), lid and lacrimal wounds (n = 9), retinal detachment (n = 4), orbital fractures (n = 3), optic nerve damage (n = 2), traumatic cataract (n = 1), lamellar lacerations of sclera (n =1), vitreous opacification (n = 1), vitreous prolapse (n = 1) and posterior vitreous detachment (n = 1).

The number of outpatient visits was 459 and hospitalization days 25. Medication was needed for 84 % (n = 125) of patients. Activity restriction was assigned for 93 % (n = 139) of patients and sick leave for 81 % (n = 120) of patients, a total of 1211 days for patients over 16 years of age. Surgery was needed for 23 % (n = 35) of patients, and the need for future surgery was estimated for six patients.

Permanent disability was estimated for 11 % (n = 17) of patients and was more common (p = 0.033) in ice hockey than in other sports in relation to the number of injuries. The need for lifelong follow-up was estimated for 72 % (n = 108) of patients.

In floorball, eye injuries diminished significantly (p = 0.03) between seasons in 2002-2003 and 2011-2012, especially among players under 14 years of age (11 vs. 1 eye injuries/6 months/1000 participants).

Table 19. Primary diagnosis, need for lifelong follow-up and permanent disability in different sports.

Sport	All	Contusion	Wound	Orbital trauma	OGT	Other	Need for lifelong follow-up	Permanent disability
Floorball	47	44 (30 %)	-	-	-	3 (2 %)	43 (91 %)	3 (6 %)
Football	19	15 (10 %)	-	1 (1 %)	-	3 (2 %)	12 (63 %)	1 (5 %)
Tennis	15	12 (8 %)	-	-	-	3 (2 %)	14 (93 %)	2 (13 %)
Ice hockey	12	10 (7 %)	1 (1 %)	1 (1 %)	-	-	10 (83 %)	4 (33 %)
Cycling	8	1 (1 %)	5 (3 %)	1 (1 %)	-	1 (1 %)	1 (13 %)	1 (13 %)
Badminton	7	7 (5 %)	-	-	-	-	6 (86 %)	2 (29 %)
Basketball	6	4 (3 %)	-	1 (1 %)	-	1 (1 %)	2 (33 %)	-
Finnish baseball	6	4 (3 %)	-	-	-	2 (1 %)	4 (67 %)	-
Combat sports	6	3 (2 %)	-	1 (1 %)	-	2 (1 %)	2 (33 %)	-
Gymnastics	4	3 (2 %)	-	1 (1 %)	-	-	3 (75 %)	1 (25 %)
Rink bandy	3	3 (2 %)	-	-	-	-	3 (100 %)	-
Cross-country skiing	3	1 (1 %)	-	-	1 (1%)	1 (1 %)	2 (67 %)	1 (33 %)
Orienteering	2	-	1 (1 %)	-	-	1 (1 %)	-	-
Gym	2	1 (1 %)	-	-	-	1 (1 %)	1 (50 %)	-
Other	9	6 (4 %)	-	-		3 (2 %)	5 (56 %)	2 (22 %)
Total	149	114 (77 %)	7 (5 %)	6 (4 %)	1 (1 %)	21 (14 %)	108 (72 %)	17 (11 %)

OGT = Open globe trauma

5.4 EYE INJURIES CAUSED BY WOODEN PROJECTILES (STUDY IV)

The study comprised 67 patients (51 males and 16 females). The mean age was 42 years (range 3–87 years). Males aged 51-67 years were at greatest risk. Two patients were lost to follow-up.

The most common activity during the accidents was playing (27 %; n = 18), gardening (18 %; n = 12) and forest work (16 %; n = 11). In relation to time spent in an activity, the risk for eye injury was highest in gardening, forest work and woodwork. More injuries occurred during spring (36 %) and autumn (27 %) months.

Protective eyewear was used by one patient, while working with a table saw.

The primary diagnoses for each activity can be seen in Table 20. Superficial bulbar or periorbital trauma (54 %; n = 36) was the most common diagnosis followed by contusion (37 %; n = 25). One eye was eviscerated because of OGT. Clinically significant secondary diagnoses were contusion (n = 2), orbital fracture (n = 3), retinal detachment or tear (n = 3), detachment of the intraocular lens (n = 1), keratitis (n = 1) and lid wound (n = 1).

The number of outpatient visits was 167 and hospitalization days 30. Medication was needed for 93 % (n = 62) of patients. Activity restriction was assigned for 84 % (n = 56) of patients and sick leave for 60 % (n = 40) of patients, a total of 405 days for patients over 16 years of age. Surgery was needed for 15 % (n = 10) of patients, and the need for future surgery was estimated for five patients.

Permanent disability was estimated for 10 % (n = 7) of patients. The need for lifelong follow-up was estimated for 37 % (n = 25).

High energy was involved in 22 % (n = 15) of cases; tools were used in ten and falling in five cases. Permanent disability was estimated for five and counted 71 % (n = 5) of all permanent disabilities, and the need for lifelong for ten patients counting 40 % of all needs for lifelong follow-up.

Table 20. Primary diagnoses, permanent disability and need for lifelong follow-up caused by wooden projectiles in relation to activity. Eleven patients had significant secondary diagnoses.

Activity	All	Contusion	Wound	Fracture	OGT	Other	Permanent Disability	Need for lifelong follow-up
Play	18 (27 %)*	7	2	-	-	9	-	7 (39 %)†
Gardening	12 (18 %)*	4	-	-	1	7	1 (8 %)†	5 (42 %)†
Forest work	11 (16 %)*	6	1	-	-	4	1 (9 %)†	5 (45 %)†
Outdoor recreation	8 (12 %)*	1	-	-	-	7	1 (13 %)†	1 (13 %)†
Woodwork	6 (9 %)*	5	-	-	-	1	1 (17 %)†	5 (83 %)†
Sport	3 (4 %)*	-	-	2	-	1	1 (33 %)†	-
Unknown/Other	9 (13 %)*	2	-	-	-	7	2 (22 %)†	2 (22 %)†
Total	67	25	3	2	1	36	7 (10 %)*	25 (37 %)*
Work-related	4 (6%)*	3	-	-	-	1	-	3
High-energy	15 (22%)*	9	1	1	1	3	5	10

OGT = Open globe trauma
*Percentage calculated from the total number of eye injuries (n = 67).
†Percentage calculated from the number of activities.

Permanent disability, need for lifelong follow-up and major surgeries in study groups is summarized in Table 21.

Table 21. Summary of permanent disability, need for lifelong follow-up and major surgeries in study groups.

Type of eye injury	Study	N	Permanent disability % (N)	Need for lifelong follow-up % (N)	Major surgeries % (N)
Eye injuries in children	II	202	9 % (19)	29 % (58)	14 % (28)
Toy gun eye injuries	III	15	47 % (7)	87 % (13)	27 % (4)
Sports eye injuries	I	149	11 % (17)	72 % (108)	15 % (23)
Wooden projectile eye injuries	IV	67	10 % (7)	37 % (25)	15 % (10)

6 DISCUSSION

This thesis comprehensively presents the epidemiology, clinical findings, diagnoses, treatments, use of resources and outcomes of new eye injuries in children, by toy guns, sports and wooden projectiles. The thesis also includes a 5-year follow-up study of toy gun eye injuries. The study setting is a population-based study of a one-year period in Helsinki University Eye Hospital, population base of 1.5 million people, including both rural and urban areas; it is comprehensive and offers essential causal connection-based data of these injuries.

Many eye injuries diagnosed in these studies could not be categorized in BETT (66 % in Study II, 13 % in Study III, 23 % in Study I and 61 % in Study IV). This may jeopardize further trauma studies that only use the BETTS classification. BETTS could be adjusted by having three, instead of two major subclasses: open globe, closed globe and adnexal trauma, including orbital fractures and eyelid or lacrimal wounds. Closed globe traumas could be adjusted with one more subclass, superficial eye traumas, as was introduced in Ophthalmology in 1996 (Pieramici, Sternberg et al. 1997, Kuhn, F., Morris et al. 2004). In this way, all injuries treated by ophthalmologists could fit some category, and the use of BETTS would be more accurate.

In the collected data, it was observed that many severe diagnoses, such as retinal or choroidal tears, retinal haemorrhage, retinal detachment and optic nerve injuries, would have been coded for primary diagnoses. Since the current WHO ICD-10 diagnosis coding system is missing ocular trauma codes (S- and T- codes) concerning those mentioned above, they could not be used. Modifying ICD-10 trauma codes, so that the listed diagnoses are included, should be considered.

6.1 RESULTS OF THE STUDY GROUPS

6.1.1 EYE INJURIES IN CHILDREN (STUDY II)

In our study, the incidence of children's eye injuries was higher (5.2–8.3 per 10 000) than in previous studies. This is understandable, since many previous studies concern children who were admitted to hospital. The incidence has been 8.9 per 100 000 in children under the age of 14 in the UK (MacEwen, C. J., Baines et al. 1999) and 15.2 per 100 000 in children aged 16 under in the USA (Strahlman, Elman et al. 1990). In our study, patients were treated mostly as outpatient visits, and only a minority of patients were hospitalised. The proportion of children's eye injuries compared with all patients treated in HUEH decreased from 34 % in 1977 to 19 % in 2011-2012 (Niiranen, Raivio 1981).

Sports equipment as the most common cause of children's eye injuries (15 %) is in agreement with a previous study in the USA, in which sports equipment accounted for 27% (Strahlman, Elman et al. 1990). Toy guns caused fewer children's eye injuries in Finland than in Denmark or in Norway (including projectiles): 6 % vs. 17 % and 22 % (Takvam, Midelfart 1993, Saunte, Saunte 2008). It is worth mentioning that fireworks caused sight

threatening eye injuries, including two OGTs, one traumatic cataract and one ischaemic area on the conjunctiva.

Interestingly, only one injury was caused by falling on a block of ice, but none were caused by snowballs, as was the case in 1977 in Finland, when snowballs were the most common cause (12/110) (Niiranen, Raivio 1981). Weather conditions influenced the prevalence of snowballs in 1977, as there was snow cover more often in 1977 than during the study period in 2011-2012 (133 vs. 97 days), which may explain the difference (Finnish meteorological institute 2019). One may also suspect if the time spent outside has reduced with the change of society. Hobbies have changed from playful outdoor activities to organizational activities such as team sports. Also, children spend more time inside with digital devices.

Tools caused 3 of 202 eye injuries. Two were OGTs, establishing 33 % of all six OGTs. Similarly, the danger of tools in the reach of children was observed in a study by MacEwen et al. (1999) in the UK , where tools caused 38 % of OGTs (MacEwen, C. J., Baines et al. 1999).

The incidence of traumatic cataracts was almost the same (7 per million vs. 5 per million) as in a 1-year Australian study concerning traumatic paediatric cataract requiring treatment (Staffieri, Ruddle et al. 2010).

Reason for permanent disability (n = 19; 9 %) was evisceration, lowered VA, glare, lack of accommodation after cataract surgery and diplopia in the up-gaze position. The causes were multiple, but in relation to the total amount of injuries compared with permanent disability, fireworks, tools, toy guns and a gun as a weapon (only one injury) were the most hazardous. From these, only toy guns are aimed for children's use.

The need for lifelong follow-up was estimated because of the elevated glaucoma risk and retinal injuries. In OGTs and in the case of evisceration, we estimated that the eyes should be examined regularly in order to ensure the eye health of the remaining healthy eye.

6.1.2 EYE INJURIES CAUSED BY TOY GUNS (STUDY III)

The incidence of airsoft eye injuries was in accordance with the previous study from Denmark (0.8 vs. 0.3/100 000 patients) (Saunte, Saunte 2008). In Israel, the incidence has been higher, 2.5/100 000 (Kratz 2010). According to Kratz et al. (2010), in Israel, airsoft guns can be purchased without any age restriction, which may explain the higher incidence. We found that toy gun eye injuries accounted for fewer of all children's eye injuries in Finland than those reported in Hong Kong (6 % versus 12 %) (Poon, A. Sy, Ng et al. 1998).

The age of airsoft players in our study was in agreement with previous studies (13.5 years vs. 9.8-18 years) (Fleischhauer, Goldblum et al. 1999, Saunte, Saunte 2006, Ramstead, Ng et al. 2008, Kratz 2010, Jovanovic, Bobic-Radovanovic et al. 2012).

In our study, the main diagnosis was contusion. In previous studies, the term 'contusion' is rarely mentioned, but one can however conclude that while 60-100 % of patients have had hyphema because of a pellet hit, and a minority was open globe injuries, contusion is the dominant type of injury (Kitchens, Danis 1999, Thach, Ward et al. 1999, Fineman, Fischer et al. 2000, Greven, Bashinsky 2006, Saunte, Saunte 2006, Baath, Ells et al. 2007, Ramstead, Ng et al. 2008, Kratz 2010, Jovanovic, Bobic-Radovanovic et al. 2012, Nemet, Asalee et al. 2016, Lee, K. M., Seery et al. 2017).

The clinical findings in our study fit in with the wide variation of clinical findings pre-

sented in previous studies: posterior findings in 47 % vs. 13–55 %, irideal trauma in 23 % vs. 11–75 % and traumatic cataract in 20 % vs. 1–33 % of patients. One patient had retinal tearing, which has not been reported from airsoft toy guns previously (Fleischhauer, Goldblum et al. 1999, Saunte, Saunte 2006, Ramstead, Ng et al. 2008, Kratz 2010, Staffieri, Ruddle et al. 2010, Jovanovic, Bobic-Radovanovic et al. 2012). The short follow-up time (mean 1.7 months, 1–540 days) may explain the low incidence (3 %) of traumatic cataracts in the study by Saunte and Saunte (2006), although the lowest incidence of 1.7 % was reported by Kratz et al. (2010), who had a follow-up of 7.6 months. It is noteworthy that in our study, all cataract patients received surgery under 12 years of age and therefore lacked normal accommodation at a young age.

We found no previous studies concerning pea shooters. However, it is meaningful to note that even pea shooters can produce severe eye trauma. Nerf guns have also been reported to cause eye injuries, but these were not found in our study (Bizrah, Verma 2017).

In our study with a 5-year control, we found abnormal clinical findings in over half (62 %) of toy gun injured patients. This proves the severity of eye injuries caused by toy guns. Interestingly, glaucoma was not found in any of the patients, despite thorough examinations and a relatively long follow-up. One patient injured by a peashooter and diagnosed with contusion, hyphema and elevated IOP had a potential risk for glaucoma but was lost to follow-up. Altogether, 40 % (n = 6) of patients had either traumatic cataract or injuries to the iris or both, which increases the risk for glaucoma. For these patients, long follow-up is needed, since glaucoma may present even decades after the injury (Sihota, Sood et al. 1995).

Permanent disability increased from assumed at the 3-month follow-up to informed subjective impairment 5 years after the injury from 33 % to 53 %.

There was no obvious reason for reported pain in any of the patients. In one patient, impaired focusing hindered the photography hobby. One patient mentioned blurry vision while bending over (interviewed by telephone), and another described it in the temporal side of the visual field, possibly due to posterior capsule opacification. Glare was described due to irideal trauma.

6.1.3 EYE INJURIES CAUSED BY SPORTS (STUDY I)

In our study, the mean age of 33 is above the mean reported previously (22-25 years) (Gregory 1986, Filipe, Barros et al. 1997, Drolsum 1999, Haring, Sheffield, Canner et al. 2016). Children accounted for 26 % of patients. The age group of 10–19 years was the largest, which is consistent with the Australian study, where the highest peak was at the age of 12-14 years of patients hospitalized because of sports-related eye injury (Hoskin, Yardley et al. 2016). Interestingly, in floorball, the age group of 40–49 years was overestimated. Similarly in Sweden, one third of floorball injured patients were older than 30 years, the majority still being in their mid-twenties (Bro, Ghosh 2017).

The male dominance of 81 % was in agreement with previous studies. Male dominance is commonly observed among eye injuries but may even increase in sports, since men are more often engaged in intensive and powerful exercise (Strahlman, Elman et al. 1990, Niiranen 1981, Filipe, Barros et al. 1997, Drolsum 1999, MacEwen, C. J., Baines et al. 1999, Koivisto 2005, Leivo, Puusaari et al. 2007, Lesniak, Bauza et al. 2012, Hoskin, Yardley et al. 2016).

We found that floorball eye injuries in Finland decreased from 45 % of all sports-related eye injuries to 32 % from 2002-2003 to 2011-2012, however, it remains the leading cause of eye injury (Leivo, Puusaari et al. 2007). The use of eye protection explains the diminished eye injuries caused by floorball in younger age groups; in 2008, eye protection became obligatory in Finland in official games among players under 15 years of age. In contrast, in older age groups, very few floorball players use protective eyewear, and hence, eye injuries in this age group have risen.

The high incidence of floorball eye injuries (32 %) reflects the risen popularity of floorball in Nordic Countries. In Sweden, floorball eye injuries increased from 19 % to 56 % from the 1990's to 2008-2011, probably due to the risen popularity (Ghosh, Bauer 1995, Bro, Ghosh 2017).

The most dangerous sports for eye healthy in relation to participants in Finland changed to rink bandy (though consisting of only three patients) from squash in 2007 (Leivo, Puusaari et al. 2007). Floorball was the second most dangerous, followed by tennis. In Norway, floorball was the most dangerous in same vein (Drolsum 1999, Leivo, Puusaari et al. 2007).

Both in Finland, Sweden and Norway, football, tennis and badminton were the other leading sports causing eye injuries (Ghosh, Bauer 1995, Drolsum 1999, Leivo, Puusaari et al. 2007). In Scotland and Portugal, the leading cause of eye injuries was football (MacEwen, Caroline 1989, Filipe, Barros et al. 1997). In the USA, basketball caused the most sports eye injuries, but football the most impairments (Kim, Thomas, Nunes et al. 2011, Cass 2012, Haring, Sheffield, Canner et al. 2016). Unexpectedly, in Australia, where cycling has been categorized as a low-risk sport and basketball a high-risk sport (Table 4), was found that among children, the highest number of sports-related injuries occurred during cycling and no eye injuries occurred in basketball (Hoskin, Yardley et al. 2016). The risk may vary between adults and children. In our study, eight (8/149) eye injuries were found, where cycling was involved, including one orbital trauma, and five out of seven eyelid wounds were primary diagnosis. Three patients were intoxicated with alcohol.

Contusion was the most common diagnosis (77 %), which has also reported previously (Drolsum 1999, Leivo, Puusaari et al. 2007). Clinically significant secondary diagnoses in 33 % of patients indicate the severity of contusions.

Permanent disability has been reported in previous studies in sports eye injuries with a wide variation of 6-31 %, placing our result of 11 % to the lower portion (MacEwen, Caroline 1989, Ghosh, Bauer 1995, Filipe, Barros et al. 1997, Drolsum 1999). In our study, the injuries occurred in various sports: ice hockey, floorball, tennis and badminton, and single incidents in football, cycling, gymnastics, cross-country skiing, Formula 1 boat racing and playing golf with a floorball club. We found that permanent disability was significantly more common in ice hockey ($p=0.033$) than all other sports combined. The reasons for permanent disability were lowered VA (due to retinal ablation, macular atrophy, retinal/choroidal/pigment epithelial tear, optic nerve damage), diplopia (due to orbital fracture), glare (due to dilated pupil), traumatic glaucoma and visual field defect (due to optic nerve damage). In paediatric patients, diplopia was the most reported complication caused by sports in the Australian study (14 %; 13/93) (Hoskin, Yardley et al. 2016). In our study, children comprised 26 % (n = 38) of all patients; diplopia after surgery was found in three patients, one of them was a child (3 %). The trauma was caused in trampoline jumping.

OTS-grading was in accordance with permanent disability, however in OTS-grading 5 was also found permanent disabilities.

6.1.4 EYE INJURIES CAUSED BY WOODEN PROJECTILES (STUDY IV)

We found that 61 % of eye injuries occurred during playing (27 %), gardening (18 %) and forest work (16 %). In the study by Tas and Hüsamettin (2014), it was found that during forest work, the occurrence of intraorbital wooden foreign bodies was 50 % (16/32), assault accounted for 16 % (5/32) and falling 13 % (4/32). Compared with our study, no assaults were observed, and falling was involved but only in four cases (6 %). Overall, forest work is shown to be a risk for eye health in both studies. Forests comprise 70 % of Finland, which is more than in many other countries, and the incidence from sticks and branches may be more common. This might also reflect in the number of injuries during play.

In our study, eye injuries from wooden projectiles was most common in males aged 51-64. In previous case series of intraocular wooden foreign bodies, the mean age varied from 21 to 36 years, though included patients up to 65 years of age (Liu, D. 2010, Shelsta, Heather N M D, Bilyk, Jurij R M D et al. 2010, Taş, Top 2014, Li, J., Zhou et al. 2016). In Finland, older men seem to be at greatest risk; they may be more active participants in forest work and gardening.

When analysing the risk of eye injury in relation to time spent in each activity, gardening, forest work and woodwork were estimated to have the highest risk for eye injuries. The use of tools may explain the increased risk in woodwork and forest work. In gardening, though, only one patient used a tool (wood chipper) and another fell. In playing, 12 out of 18 patients were under 10 and were not included in the risk analysis.

One OGT was caused as a result of falling during gardening. Surgery was needed because of evisceration, retinal procedures and suturing for the eyelid and conjunctival tear, including one lacrimal duct tear.

The incidence of intraorbital foreign bodies is rare, as evidenced by our study, in which only one patient had an intraorbital wooden foreign body (Shelsta, Heather N M D, Bilyk, Jurij R M D et al. 2010, Li, J., Zhou et al. 2016). The challenge in wood-induced eye traumas to identify wood in radiological imaging was observed also in our study. In our patient the radiological finding was reported as “air in intraorbital space”, but since wood was suspected, the report was corrected (Specht, Varga et al. 1992, Fulcher, McNab et al. 2002, Kim, Usha R., Sivaraman 2013, Desai, A., Parihar et al. 2014, Clark, Fernandez de Castro, J P et al. 2016, Li, J., Zhou et al. 2016, Liu, D. 2010).

In our study, only one keratitis was diagnosed. The microbe was not identified, and the patient healed properly. Several reports of keratitis, endophthalmitis or cellulitis exist as caused by wooden material (Lai, T. Y., Kwok et al. 2001, Taylor, Wiffen et al. 2002, Bergmann, Lee et al. 2009, Chew, Jungkind et al. 2010, Shelsta, Heather N M D, Bilyk, Jurij R M D et al. 2010, Taş, Top 2014, Liu, M., Xin et al. 2015, Clark, Fernandez de Castro, J P et al. 2016). However, the incidence of wood-associated orbital or ocular infections or keratitis has not been reported. According to our study, infections are rare.

Permanent disability was expected for patients diagnosed with contusions, orbital fractures and OGT. The reasons were lowered VA, diplopia, glare and evisceration. Injuries causing permanent disability were found in all activities except during play.

The need for lifelong follow-up was estimated for patients diagnosed with contusions and OGT. The reasons were a risk for glaucoma, retinal tears and ensuring the eye health of the other eye after evisceration. Playing did not cause any permanent disability, but 7 of

18 patients were estimated to need lifelong follow-up because of contusions and increased glaucoma risk.

6.2 RESOURCE USE

In our study, patients needed hospitalization in fewer cases than in the Singaporean study (interview of patient cohort aged 40 to 80) (6-13 % vs. 20 %) (Wong, Man et al. 2018). Also, the duration of hospitalization in children was clearly shorter than in the Croatian study (3 vs 10 days) (Bućan, Matas et al. 2017). In Finland, for example, patients with a bleeding in the anterior chamber are generally treated by outpatient visits, while in many other countries, they are hospitalized. Toy gun injured patients (Study III) needed the most control through outpatient care (6 vs. 2-3 visits per patient), but hospitalization was most needed for patients injured by wooden projectiles (Study IV; 13 % vs. 6-8 %). No obvious explanation for the difference in hospitalization was found. Interestingly wooden projectiles -injured hospitalized patients were older than patients in other groups.

Major surgery was needed the most in relation to the number of patients in toy gun injured patients (27 %) (Study III). In children, anaesthesia is often needed even for smaller procedures, as was the case in 67 % of all surgeries (Study II).

The need for lifelong follow-up was needed most in injuries caused by toy guns and sports (87 and 72 %, Study III and I). The main reason for the need for lifelong follow-up was an increased risk for glaucoma due to contusion in all studies. A 3–4 % incidence of glaucoma after ocular contusions has been reported in a 6-month follow-up and up to 10% in a 10-year follow-up (Kaufman, Tolpin 1974, Girkin, C. A., McGwin et al. 2005).

Sports caused more need for sick leave (81 %) than wooden projectiles (63 %). In Study II and III, where almost all patients were children, sick leave days were not determined because, for example, the estimation of when a child is old enough to stay at home alone is arguable. In spite of this, some losses were incurred by the employers of the parents. In this category, it is notable that even minor injuries, such as corneal abrasion, caused absence from work.

In further studies, it would be relevant to estimate and calculate the real costs of eye injuries.

6.3 PREVENTION AND EYE PROTECTION

Eye protection gear is an easy way to protect the eyes, but it is often forgotten or neglected. Ophthalmologists have an important role in the education of eye protection.

Eye protection is essential, especially in amblyopic children and functionally one-eyed people, who have an increased risk of becoming blind compared with the general population (Tommila, Tarkkanen 1981). These people presumably follow up with their ophthalmologist regularly. In these cases, the ophthalmologist should emphasise eye protection or advise against high-risk sports and work assignments. Unfortunately, no-one was advised for this by an ophthalmologist or nurse according to study in UK (Ong, Barsam et al. 2012).

Eye injuries in children (Study II)

Tools, fireworks and guns caused serious eye injuries. In children, enhancements to the supervision and safe environment, e.g. proper supervision or denying access to guns and fireworks would have helped in the prevention of eye injuries in our studies (Podbielski, Surkont et al. 2009, Pollard, Xiang et al. 2012, Philip, Hoskin 2014, Yardley, Hoskin et al. 2017). In case of tools, proper supervision and education would have been desirable, as concluded in the review article by Hoskin et al. (2016).

The use of eye protection might have prevented eye injuries caused by fireworks in three out of four cases. Still, despite the use of protective eyewear, one bystander was injured resulting in a traumatic cataract. In 2010, Finland legislated a new law, prohibiting the handling of fireworks by those under the age of 18, restricting certain type of fireworks and reducing the duration of the New Year firework season. Firework-caused eye accidents diminished from 47 to 11 on New Year's 2014 but rose to 29 after New Year's 2015 (Kivelä 2014, Kivelä 2016). After New Year's 2019 the number of firework-caused eye injuries decreased to five (Kivelä 2020). In 2018, the citizen's initiative set forth the goal to change the law to prohibit consumer use of fireworks.

Eye injuries caused by toy guns (Study III)

Four patients (27 %) used protective eyewear during the game (three airsoft, one paintball), but the glasses were removed due to discomfort prior to injury; the protective eyeglasses were described as too big, dirty or misty. Similarly, Fineman et al. (2000) had noted that 60 % of patients harmed by a paintball had initially been wearing protective eyewear, but 86 % of those injured had removed them mainly because of fogging and paint splatter.

In our study, at least half (53 %) of eye injuries occurred outside formal games. Also, in the study by Greven et al. (2006) concerning paintball games, 47 % of eye injuries took place outside the game and only 11 % occurred during a formal game. In our study, 2 of 15 patients were bystanders, and a toy gun had been used outside of a formal game in six cases. A toy gun could be used, for instance, with the assumption that the gun is not loaded, when aiming at someone. Similar situations were described in the study by Greven (2016); for example, a paintball gun was handled inappropriately, i.e. discharged at close distance between a friend or a family member.

Concerning toy guns, the danger of them outside arranged games appears to be ignored, leading to their irresponsible use. In Finland, airsoft guns are classified as airguns, but product marketing and the safety of toy guns and protective equipment are controlled by The Finnish Safety and Chemical Agency. Sellers are advised to inform buyers about the regulations and hazards. If airsoft guns were to fall under the Firearms Act, their hazards might be better understood. In Denmark, the law prohibits the use of pellet toy guns by persons aged under 18, and in Australia, they are entirely forbidden (Saunte, Saunte 2006, Dain 2016).

Eye injuries caused by sports (Study I)

It was found that floorball eye injuries declined in the under 14 age group in a 9-year inter-

val (season 2002–03 to 2011–12) from 11 to 1 (in an equal 6-month period) (Leivo, Puusaari et al. 2007). The Finnish Floorball Federation demanded protective eyewear as mandatory in floorball for players under 15 years of age back in 2008, which has now proven to be effective in preventing eye injuries. The result is in agreement with a study from Sweden, in which eye injuries among young floorball players diminished distinctly after the use of eye protection (Bro, Ghosh 2017).

In ice hockey, the use of visor in the 1970's significantly reduced eye injuries in Canada, and visor use is obligatory in official Finnish ice hockey for all age groups (Pashby, Pashby et al. 1975, Pashby 1979). In our study, despite the use of a visor, four serious eye injuries occurred in ice hockey.

In our study, the most sports injuries (43 %) occured in casual or amateur sport practice and less during competitions, organised team practice, school or day care sports or occupational sports. In ice hockey, half of eye injuries occurred during unofficial games and in 8 of 12 cases, the visor was not in use. Also, in Sweden, it was observed that in floorball, most eye injuries occurred during a casual game (Bro, Ghosh 2017). These results show that the use of eye protection is ignored and the activity is without supervision.

Eye injuries caused by wooden projectiles (Study IV)

The use of eye protection would likely have prevented or reduced eye injuries in woodwork and forest work, in which the use of eye protection is recommended (The Centre for Occupational Safety , Kuusisto, Varpula et al. 2005). However, the use of protective eyewear did not prevent eye injury while working with a table saw. In addition, some accidents occurred unexpectedly in activities, where eye protection is not generally an issue. More attention should thus be focused on eye injuries, when working with tools or in forestry, as in other activities in which tools are commonly used. The short working distance to branches may increase the risk for eye injuries in gardening, where the use of protective eyewear is not routine.

6.3.1 COMPLIANCE

Compliance in using protective eyewear would increase, if the gear was more comfortable. As seen in ice hockey, a visor can effectively prevent eye trauma only when fitted and used correctly; it should be worn and positioned to cover the eyes and the lower edge of the nose in all projections. In toy gun eye injuries, abandoning the use of eye protection before the accident because of discomfort is worrisome. Likewise, in our study, abandoning protective eyewear has been reported to be due to fogging, dirty goggles, discomfort and disturbance of vision both in paintball and floorball (Fineman, Fischer et al. 2000, Bro, Ghosh 2017, Chatterjee, Agrawal 2017). Protective eye wear must fulfil both the demands of safety and of a user-friendly product. They must have a sufficient field of view, have a clear and undistorted picture, produce light scattering and provide sufficient coverage to the eyes (Dain 2016). More product development is needed though.

In protective eye glasses, polycarbonate or Trivex (PPG Industries, Pittsburgh, Pennsylvania, USA) are the recommended materials for protective eyewear due to durability,

impact resistance and light weight (Pashby, Pashby et al. 1975, Lincoln, Caswell et al. 2012, Mishra, Avinash, Verma 2012, Hoskin, Philip et al. 2016).

6.4 LIMITATIONS OF THE STUDIES

The weakness of Studies I, II and IV is the short 3-month follow-up. Most disabilities, such as lowered VA due retinal or corneal scaring, evisceration and glare, can be seen in a short follow-up. A longer follow-up would likely have a positive impact, since VA may improve after cataract and retinal surgery, and diplopia may diminish over time in some patients. Also, the treatment for amblyopia may improve VA with time. On the other hand, many eye injuries carry a long-term risk of visual impairment, which can be diagnosed only several years or even decades after the incident.

The relatively small number of patients in Studies III and IV is another weakness. However, it is worth mentioning that almost all patients in Study III (13/15, 87%) attended the 5-year re-examination.

Though the data of study is rather comprehensive, some of the minor injuries may not have been included in this study. Some minor eye injuries have been treated in healthcare centres, occupational primary care or private healthcare facilities or injuries have recovered without any need of medical care. Therefore, the true number of all minor eye injuries, such as superficial foreign bodies, is higher. It is also possible that single, critically ill, intensive care and unmovable patients may have been treated at the university general trauma hospital, who would not have been included in this study. One additional, small, non-emergency, secondary care eye unit exists in the area which was not included to the study. During office hours, it may have treated sporadic minor eye trauma that did not require surgical care; these cases were also not included in the study.

7 SUMMARY AND CONCLUSIONS

The most common severe eye injuries were found among children and to be caused both by toy guns, sports and wooden items.

In children the most common cause was a hit from sporting equipment. Injury was most likely at the age of 13 to 16 years. Protective eyewear was used by 3 out of 4 patients (fireworks, toy gun and welding).

Toy gun eye injuries were caused mainly by airsoft guns, including two cases of pea shooters and one case of paintball. Patients were mostly young men, with a mean age of 15 years. Protective eyewear was used by 4 out of 15 (27 %) patients but the use was inappropriate.

Sports that caused most eye injuries were floorball, football and tennis. In relation to participants, rink bandy was the most dangerous. Sporting equipment was the main cause. The majority of the eye injuries occurred at age 10-19, but in floorball, eye injury was most common at age 40-49. The study shows, that protective eyewear in junior floorball is ef-

fective in preventing eye injuries: eye injuries diminished significantly ($p = 0.03$) between seasons 2002-2003 and 2011-2012 among players under 14 after the Finnish Floorball Federation made protective eyewear mandatory.

Wooden projectiles caused eye injuries mainly during playing, gardening and forest work. In relation to time spent gardening, forest work and wood work were the most dangerous to eye health. Injury was most likely in males aged 51-67. Tools were involved in most cases causing permanent disability. The use of eye protection did not protect three patients from eye injury who used a table saw.

The main diagnosis was contusion caused by toy guns (87 %) and sports (77 %). Mild ocular or periocular traumas were the most common diagnosis in case of wooden projectile eye injuries (54 %) and among children (50 %). Open globe trauma was found in 3 % of children (n = 6) and in 1 % (n = 1) caused both by sports and wooden items.

Major surgery was needed for 14-27 % of patients, including two eviscerations, suturing of OGTs, several retinal procedures and traumatic cataract operations. The number of outpatient visits was from 2 to 6, as calculated per patient, toy gun injuries needing the most outpatient visits. Activity was restricted because of eye injury in 71 % (children) to 100 % (toy guns) of patients.

Permanent disability was estimated for 9 % of children and for 47 % injured by toy guns, 11 % injured by sports and 10 % injured by wooden projectiles. The need for lifelong follow-up in children was found to be 29 % and in 87 % of cases caused by toy guns, 72 % in sports, 37 % in injuries caused by wooden projectiles. These highlight the severity of toy guns with regard to permanent disability, and the high risk of sports and toy guns regarding the need for lifelong follow-up. Also, it is notable that in every category, disability cases could be found. In a 5-year follow-up, no glaucoma was found, but 50 % had subjective impairment: pain, blurred vision, lowered VA or glare.

Recommendations

Fireworks are still causing serious eye injuries in children and their use should be more restricted. Tools and sticks were observed to be dangerous for children's eye health, therefore, children should be supervised and guided more actively when using them.

In toy gun games, proper protective eyewear should be used during the entire game and their use should be more supervised. The hazards of toy guns should be made more obvious; we recommend restricting the selling of airsoft guns by being placed under the Firearms Act.

In floorball, protective eyewear should be mandatory for all age groups. In ice hockey, the proper use of a visor should be emphasised, and visor use in casual or amateur practice should be encouraged. Protective eye wear is recommended during gardening, forest work and woodwork.

The use of eye protection can prevent many eye injuries. More attention should be paid on improving the usability and quality of protective eyewear, which presumably increases the compliance of their use. Use of eye protection should be informative, regular and supervised.

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ORIGINAL PUBLICATIONS

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SPORTS-RELATED EYE INJURIES: THE CURRENT PICTURE.

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Sports-related eye injuries: the current picture

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ABSTRACT.

Purpose: **This study aims to represent the epidemiologies, findings, treatments, use of resources, outcomes and protective-eyewear-use recommendations in sports-related eye injuries by sport type.**

Methods: **The study population is comprised of all new eye injury patients in 1 year in Helsinki University Eye Hospital. Data were collected from patient questionnaires and hospital records. The follow-up period was 3 months.**

Results: **149/1151 (12.9%) of eye injuries were sports-related. Thirty two percent were related to floorball (type of hockey played on a mat with a stick and a ball); football, tennis and ice hockey were the next most common eye-injury-causing sports. Relatively, the most dangerous sports were rink bandy, (bandy played on ice hockey rink with a stick and a ball) (0.50 injuries in 12 months/1000 participants, CI 0.10–1.46), floorball (0.47, CI 0.34–0.62) and tennis (0.47, CI 0.26–0.77). Contusion was the primary diagnosis in 77% of cases; 41% of contusion patients had severe, mainly retinal findings. The number of outpatient visits was 459; inpatient days 25 and major surgeries 31. One hundred and eight patients were estimated to need life-long follow-up. Seventeen patients had a permanent functional impairment, 4 in ice hockey, 3 in floorball, 2 each in tennis and badminton.**

Conclusion: **Compared to a previous study, ice hockey eye injuries are increasing and relatively severe, and a third of these injuries occurred despite visor use. Floorball eye injury incidence has significantly declined, mainly due to recently enforced mandatory protective eyewear for younger age groups. Based on these findings, we recommend, in floorball, that protective eyewear should be mandatory in all age groups. Universally in ice hockey, the proper use of a visor should be emphasised.**

Key words: epidemiology – floorball – ice hockey – ocular trauma – outcome – protective eyewear – sports – visor

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Introduction

Practicing sports is amongst the most common causes of eye injury, especially amongst children and young adults. Most sports eye injuries are preventable using protective eyewear and thus mandate the need for current epidemiological data. In several Nordic and central European countries, there is a special interest in floorball eye trauma, because it has been reported to cause the majority of injuries (Ghosh & Bauer 1995; Drolsum 1999; Leivo et al. 2007; Maxen et al. 2011). In a previous Finnish study, 17% of all eye injuries were sports related, and of these, 45% were caused by floorball (Leivo et al. 2007). As this finding, the Finnish Floorball Federation made protective eyewear mandatory in junior floorball. The effectiveness of mandatory eyewear in floorball has not been previously reported.

The objectives of this study are to (1) determine the current epidemiology of sports-related eye injuries, (2) review the treatments, use of resources and outcomes of these injuries and (3) give up-to-date evidence-based recommendations for the use of protective eyewear in sports.

Materials and Methods

The study population was comprised of all new, sports-related eye injury patients in the Emergency Clinic of the Helsinki University Eye Hospital (HUEH) in 1 year, 1 May 2011 to 30 April 2012. The HUEH is a tertiary and secondary care eye hospital in Finland, whose population base is 1.5 million. The hospital register was accessed to gather data on all eye emergency patients during this period who were assigned an ICD-10 diagnosis indicating eye injury. During their first visit, all eye injury patients were given a questionnaire to fill out.

To obtain full coverage of the data, first, the eye injury patients were selected in the emergency clinic to fill out the questionnaire; secondly, the hospital records were accessed to find any possible missed out-patients who had an ICD-10 diagnosis indicating eye injury directly or indirectly, that is, we also searched clinical practice for any incorrect non-trauma diagnoses. Thirdly, the researchers examined all the relevant case histories to confirm the accuracy of the injury details.

The questionnaire dealt with detailed information about the trauma-causing event and circumstances. If a patient did not complete a questionnaire, researchers collected

all possible patient background data from their health records. In addition, the questionnaire included questions on previous sports eye trauma to themself or a sport-mate; their current use and willingness in the future to use protective eye wear; and a self-assessment of the potential degree of dangerousness of their sport to the eyes.

Information on personal data, status findings, diagnoses, treatments, use of healthcare resources, sick leave and sports restrictions was collected from case histories.

The epidemiological data were analysed and the distributions represented. The percentages were calculated from the reported results. If the proportion of unavailable data was over 10%, the number of missing cases was reported. The yearly incidence of eye injuries per 1000 participants in different sports was compared by determining the proportion of injuries relative to the estimated number of participants in the sport in the Hospital District of Helsinki and Uusimaa (HUS). The estimated number of participants was calculated by dividing the participant population in the national fitness study in 2009–10 (SLU – Suomen Liikunta ja Urheilu 2010) with the population proportion in the HUS district in 2011. 1.5 million people, 28.6% of the total population of Finland, lived in the HUS district in 2011 (HUS 2012). Incidence rate confidence intervals were calculated by exact method. Age distribution and ICD-10-based primary diagnoses by sports were calculated.

The ocular yearly injury incidence in different sports was compared between the current 2011–12 data and 2002–03 data. As the latter (Leivo et al. 2007) data set was collected for a 6-month period, and many sports are to some extent seasonal, the comparison was performed for an equal, 6-month time period, 3.12–3.6. 95% confidence intervals and a chi-square distribution test were used for statistical analysis of incidence rate differences.

Clinically, the most significant status finding by each anatomical location was reported in different diagnosis groups. Use of different healthcare resources, sick leave and physical activity restriction was represented by number of involved patients, mean and range per involved patient and total number of resource units used.

Data were collected for a 3-month post-traumatic period. If the follow-up visits of minor eye trauma in the 3-month period were referred outside Helsinki University Eye Hospital, their planned number was collected from the individual case records. If miscoding was noticed in the clinical practice, diagnosis coding was corrected. If the sick leave or sports restrictions were not recorded in the records, the need for them was estimated based on international recommendations and the individual clinical status findings (Recchia et al. 2002; Walton et al. 2002; Tsai et al. 2011; Gerstenblith & Rabinowitz 2012).

If several injuries were present in the eye or its vicinity, the clinically most significant trauma diagnosis (ICD-10 S- or T-diagnoses) was recorded as the main diagnosis. Floorball and its amateur version floor hockey were combined into one discipline. Airsoft gun eye injuries were classified as playing activity and were not included in the study.

For each patient, the final status was recorded, including the final visual acuity, the intraocular pressure and the main abnormal status findings. The severity of eye trauma was presented using OTS grading (Kuhn et al. 2002), including the estimated need for lifelong follow-up (Recchia et al. 2002; Walton et al. 2002; Tsai et al. 2011; Gerstenblith & Rabinowitz 2012) or future eye surgery and the estimated permanent functional visual impairment due to abnormal visual acuity or other symptoms. The proportion of severe eye trauma in different sports was presented. The four biggest eye-injury-causing sports were statistically analysed, comparing the sport where the proportion of permanent impairment was highest to all other sports combined by Fisher's exact test.

Informed consent and local ethics committee approvals were provided for the study.

Results

Background information

In a 1-year period, the Helsinki University Emergency Clinic treated 1151 new eye injury patients, 149 (12.9%) of whom were sports injury patients. The patient records of all sports-related eye trauma patients were accessed. One hundred and eight patients (72%) filled out the questionnaire.

Floorball was the leading eye-injury-causing sport, accounting for 47 injuries, 32% of all sports-related eye traumas. Football caused 19 eye injuries, tennis 15 and ice hockey 12 (Fig. 1).

The distribution of different sports causing eye injuries is presented in Table 1 according to age groups, each spanning 10 years. The mean age of sports eye injury patients was 33 years. The largest number of all eye traumas

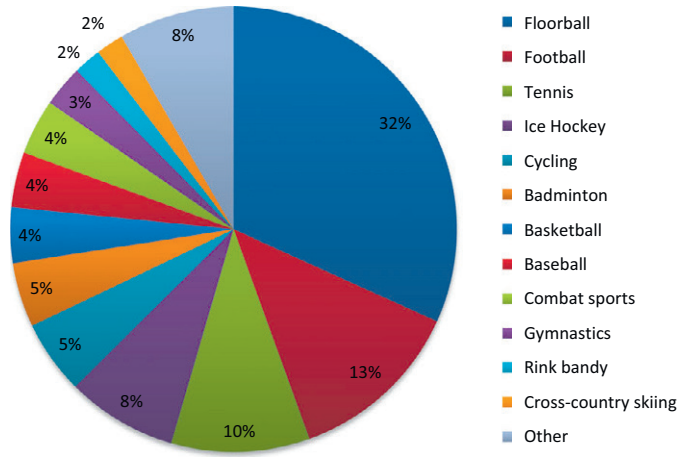

Fig. 1. Sports causing eye injuries.

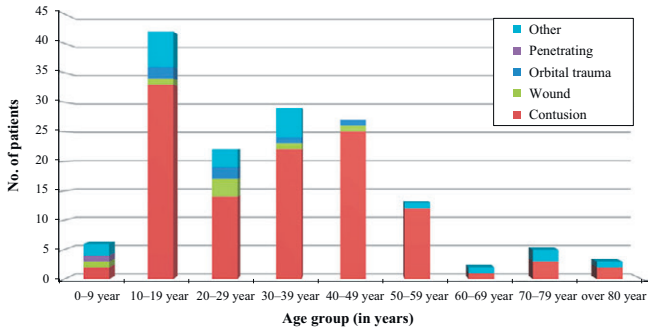

Fig. 2. Primary diagnoses of sports-related eye injuries in 10-year age groups. In addition, 49 patients had secondary diagnoses.

Table 1. Age distribution of sports-related eye injuries by sports.

	Age group (in years)									
Sport	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	Over 80	All
Floorball	3	9	6	10	15	3	0	1	0	47
Football	0	9	2	3	2	3	0	0	0	19
Tennis	0	3	2	1	1	2	1	3	2	15
Ice hockey	0	3	6	2	1	0	0	0	0	12
Cycling	1	1	2	1	1	1	0	0	1	8
Badminton	0	1	0	2	2	2	0	0	0	7
Basketball	0	3	1	0	1	0	1	0	0	6
Baseball	0	3	1	0	1	0	1	0	0	6
Combat sports	0	0	2	4	0	0	0	0	0	6
Gymnastics	0	2	0	1	0	1	0	0	0	4
Cross-country skiing	1	1	0	0	0	0	0	1	0	3
Rink bandy	0	1	0	0	2	0	0	0	0	3
Orienteering	0	0	1	1	0	0	0	0	0	2
Gym	0	1	0	1	0	0	0	0	0	2
Other	1	3	0	2	2	1	0	0	0	9
All	6	41	22	28	27	13	2	5	3	149

Table 2. Estimated incidence of sports eye injuries treated in the Hospital Districts of Helsinki and Uusimaa (HUS) relative to the number of people participating in different sports.

Sport	No. of injuries/ 12 months, *n* (%)	No. of participants in HUS district	No. of injuries/1000 participants/12 months, *n* (95% CI)
Floorball	47 (32)	101 000	0.47 (0.34–0.62)
Football	19 (13)	102 000	0.19 (0.11–0.29)
Tennis	15 (10)	32 000	0.47 (0.26–0.77)
Ice hockey	12 (8)	57 000	0.21 (0.11–0.37)
Cycling	8 (5)	331 000	0.02 (0.01–0.05)
Badminton	7 (5)	49 000	0.14 (0.06–0.29)
Basketball	6 (4)	16 000	0.38 (0.14–0.82)
Baseball	6 (4)	15 000	0.40 (0.15–0.87)
Combat sports	6 (4)	24 000	0.25 (0.09–0.54)
Gymnastics	4 (3)	211 000	0.02 (0.01–0.05)
Rink bandy	3 (2)	6000	0.50 (0.10–1.46)
Cross-country skiing	3 (2)	266 000	0.01 (0.00–0.03)
Orienteering	2 (1)	14 000	0.14 (0.02–0.52)
Gym	2 (1)	242 000	0.01 (0.00–0.03)
Other	9 (6)	n/a	n/a

was observed in the 10–19 age groups, but for floorball eye trauma, in the 40–49 age groups. Floorball was the leading or co-leading eye-injury-causing sport in all age groups under 60 years of age. In the 10–19 and 50–59 age groups, floorball and football caused an equal number of eye traumas. In age groups over 60 years of age, tennis was the leading eye-injury-causing sport. Overall, sports-related eye trauma was rare in patients under 10 and over 60 years of age (Fig. 2). Eighty-one percent of sports-related eye injury patients were male.

Forty-three percent of sports injuries occurred in non-organised sport practice, 19% in competitions, 19% in organised team practice and 14% in school or day care sport and 4% in occupational sport. The data were not available in 45/149 cases.

In 79% of cases, the injury-causing object was sports equipment; in 12%, it was a body part. In floorball, the ball caused 85%, the stick 11% and a body part 4% of the injuries. In football, 83% were caused by the ball and 17% by a body part. In tennis, all injuries were caused by the ball, and at least five injuries were reported to be caused by the patient's own hit of the tennis ball. In ice hockey, 70% were caused by the stick and 30% by the puck.

Of the reported cases, 60% of the eye injuries were caused by the opponent team player, 21% by an own team player and 19% were self-inflicted; data were not available in 52/149 cases. A sports violation was involved in 4% of reported cases: two in ice hockey, one in floorball and one in football; data were not available in 52/149 cases.

Three cycling injury patients were reported to be intoxicated by alcohol. None of the sports-related eye injuries was reported to be intentional.

The estimated incidence of sports eye injuries relative to the number of people participating in different sports is presented in Table 2. Relatively, the most dangerous sports were rink bandy, 0.50 injuries in 12 months/1000 participants; however, the absolute number of eye traumas was only 3 and subsequently the CI 0.10–1.46. The next highest sports eye injury incidences were in floorball (0.47, CI 0.34–0.62), tennis (0.47, CI 0.26–0.77), Finnish baseball (0.40, CI 0.15–0.87) and basketball (0.38, CI 0.14–0.82).

Primary and secondary diagnoses, initial clinical findings and surgical treatments

The primary eye trauma diagnoses in different sports are presented in Table 3. In addition to the primary diagnosis, 49 (33%) patients had clinically significant secondary diagnoses (other than superficial lid or bulbar trauma). Detailed anatomically categorised clinical status findings in different primary diagnosis groups of the first hospital visit are available in Table S1.

Contusions

Contusion was the primary diagnosis in 114 (77%) injuries. In addition, five patients had contusion as a secondary diagnosis. Contusion was the most common primary eye injury in all sports where at least two injuries were observed during the 12-month period; exceptions included cycling and orienteering, where 'lid and lacrimal wound' was the most common primary diagnosis. In the first hospital visit, 46 (41%) contusion patients had visual acuity <1.0 (20/20). Twenty-two (20%) patients had intraocular pressure over 21 mmHg. Twenty-nine (26%) contusion patients had macroscopic hyphema; 61 (54%) patients had microscopic hyphema or anterior cell reaction. Twenty-one (16%) contusion patients had normal anterior chamber. None of the patients had secondary anterior chamber haemorrhage. Ten (9%) contusion patients had macular retinal oedema and 28 (25%) had peripheral retinal oedema.

Thirty-six (32%) contusion patients had one or several clinically significant secondary diagnoses. Ten (9%) had a retinal tear treated by argon laser photocoagulation; 9 (8%) retinal haemorrhage; 8 (7%) a lid or lacrimal wound needing surgical treatment; 6 (5%) vitreous haemorrhage; 3 (3%) retinal detachment with retinal break treated by vitrectomy and liquid–gas exchange. One of three retinal detachments was only first noticed on a follow-up visit. Three (3%) contusion patients had an orbital fracture and 2 (2%) contusion patients had an optical nerve injury. In addition, one of each of the following secondary diagnoses was observed: trauma cataract, non-penetrating scleral tear, choroidal tear, vitreous prolapse, vitreous opacification and posterior vitreous detachment.

Lid trauma

Lid trauma was the primary diagnosis in seven cases, of which five occurred in cycling, one in orienteering and one in ice hockey. The orienteering trauma was incurred when running and bumping into a tree branch, causing lid trauma and an orbital fracture, which was non-surgically treated. Nine patients had lid trauma as a secondary diagnosis: six incurred in ice hockey, one each in cycling, mix-match floorball-stick-golf ball and golf. All 16 primary and secondary lid trauma patients needed surgical repair; two also needed lacrimal reconstruction.

Orbital trauma

Orbital trauma was the primary diagnosis in six cases, all needing surgical repair. Three of these patients had an orbital fracture and no clinically significant secondary diagnoses; these injuries occurred in basketball, football and trampoline gymnastics. A fourth orbital fracture injury occurred in basketball, causing secondary contusion. A fifth occurred in ice hockey, causing secondary contusion and retinal detachment, and a sixth in cycling, causing a penetrating orbital wound by a wooden foreign body, contusion and lid and lacrimal wound. Orbital fracture was the secondary diagnosis in three patients, one each in orienteering, rink bandy and a mix-match floorball-stick-golf ball sport. None of these required surgical treatment.

Penetrating injury

One penetrating injury was caused by a ski pole in cross-country skiing. This zone I corneal penetrating injury could be treated with a contact lens.

The use of resources

The use of healthcare resources, sick leave and activity restrictions in the 3 months following eye injury is presented in Table 4. One hundred and forty patients were treated in the outpatient ward, and only nine patients needed inpatient ward care. The total number of outpatient visits was 459, and inpatient days totalled 25.

Twenty-three patients (17%) needed major surgery in an operating theatre, including 31 procedures: 16 lid suturations (including 2 lacrimal canalicular repairs and silicone intubation); six orbital and periorbital fracture repairs; and four retinal surgeries (including 3 vitrectomies with fluid–gas exchange and 1 transscleral cryo with plomb implantation). Twelve patients needed minor surgery, including 11 retinal argon laser coagulations and one corneal foreign body removal.

Eighty-one percent of patients were estimated to need sick leave: mean 10.1 days (range 1–161, SD 17) per involved patient. At least 28 days of sick leave were needed in 10 (7%) cases: ice hockey (4), floorball (2),

Table 3. ICD-10-based primary* diagnosis groups of sports-related eye injuries.

Sport	Contusion, *n* (%)	Wound, *n* (%)	Orbital trauma, *n* (%)	Penetrating, *n* (%)	Other†, *n* (%)	All, *n*
Floorball	44 (30)	0 (0)	0 (0)	0 (0)	3 (2)	47
Football	15 (10)	0 (0)	1 (1)	0 (0)	3 (2)	19
Tennis	12 (8)	0 (0)	0 (0)	0 (0)	3 (2)	15
Ice hockey	10 (7)	1 (1)	1 (1)	0 (0)	0 (0)	12
Cycling	1 (1)	5 (3)	1 (1)	0 (0)	1 (1)	8
Badminton	7 (5)	0 (0)	0 (0)	0 (0)	0 (0)	7
Basketball	4 (3)	0 (0)	1 (1)	0 (0)	1 (1)	6
Baseball	4 (3)	0 (0)	0 (0)	0 (0)	2 (1)	6
Combat sports	3 (2)	0 (0)	1 (1)	0 (0)	2 (1)	6
Gymnastics	3 (2)	0 (0)	1 (1)	0 (0)	0 (0)	4
Rink bandy	3 (2)	0 (0)	0 (0)	0 (0)	0 (0)	3
Cross-country skiing	1 (1)	0 (0)	0 (0)	1 (1)	1 (1)	3
Orienteering	0 (0)	1 (1)	0 (0)	0 (0)	1 (1)	2
Gym	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	2
Other	6 (4)	0 (0)	0 (0)	0 (0)	3 (2)	9
All, *n* (%)	114 (77)	7 (5)	6 (4)	1 (1)	21 (14)	149

* In addition, 49 patients had clinically significant secondary diagnoses.
† Superficial eye or lid injury.

Table 4. Use of healthcare resources, sick leave and activity restriction in sports-related eye injuries.

Resource	No. of Patients	Mean/ Involved patient	Range/ Involved patient	Total number of resource unit used
Outpatient visits (university clinic)*	149	2.8	1–12	412
Outpatient visits (elsewhere)†,‡	38	1.2	2–4	47
Inpatient days	9	2.8	1–8	25
Major surgery	23	1.3	1–6	31
Minor surgery	12	1.0	1–1	12
Medication	125	–	–	–
Sick leave (days)‡	120	10.1	1–161	1211
Physical activity restriction (days)‡	139	21.5	3–90	2982

* First 3 months.
† Estimated.
‡ If not marked in the records, estimate based on international recommendations.

badminton (2), Formula One (F1) motorboat sport (1) and cycling (1); the primary diagnosis was contusion in eight cases and orbital trauma in 2. The need for at least 4 weeks of sick leave was due to a contusion causing retinal trauma (in six cases), a prolonged anterior chamber reaction and need for dilating drops, a persistent high eye pressure and dilated pupil, a suspected optic nerve injury and penetrating orbital trauma including orbital fracture. In total, these patients had four retinal, two orbital and two lid surgeries, and eight of these patients had abnormal final visual acuity (VA 0.12–0.8).

Ninety-three percent of patients were estimated to need activity restriction: mean 21.5 days per involved patient (range 3–90 days, SD 13.0).

The total number of sick leave days was estimated to be 1211, and the total number of physical activity restriction was 2982 days.

The final clinical findings and future risk estimate

The need for lifelong follow-up, future surgery and permanent functional impairment by sports is shown in Table 5, and the OTS classification by sports is shown in Table 6.

One hundred and eight patients were estimated to need lifelong follow-up (Table 5). One patient was estimated to need lifelong follow-up due to a penetrating injury. Eighty-three patients were estimated to need lifelong follow-up due to a contusion-caused future glaucoma risk, 23 patients due to a contusion-caused glaucoma risk in addition to having a retinal or vitreous injury; and one patient due to a contusion-caused glaucoma risk in addition to corneal Fuchs dystrophy in the trauma eye and previous penetrating keratoplasty in the fellow eye.

Seven (5%) patients were estimated to need a total of nine additional major eye surgeries in the near future. Two patients were already scheduled for a cataract operation, and further, two patients were estimated to need a cataract operation later. Four patients were estimated to need further vitreoretinal surgery and one patient a lid surgery and lacrimal surgery.

In the 3-month follow-up period, 17 (11%) patients were estimated to have a permanent functional impairment due to a sports-related eye trauma (Table 5): ice hockey (4), floorball (3), tennis (2), badminton (2) and one patient each in football, cycling, cross-country skiing, trampoline gymnastics, F1 motorboat sport and mix-match floorball-golf. In addition, two patients (1%), one in floorball and one in ice hockey, had a high probability of having a permanent functional impairment, but were lost in follow-up.

In ice hockey, three patients had lowered final visual acuity. The first patient had a visual acuity of 0.1, contusion, retinal haemorrhage, unoperated orbital fracture, macular atrophy, choroidal – and pigment epithelia tear in the papillomacular area. The second patient had a visual acuity of 0.5, operated orbital fracture, contusion and operated retinal ablation. The third patient had a visual acuity of 0.7 and a permanent wide pupil causing glare, contusion and an operated lid trauma. In ice hockey, a fourth patient had permanent functional impairment due to iris dialysis causing glare; he had contusion and operated lid trauma as secondary diagnoses. Relative to the number of injuries, a permanent impairment was significantly more common ($p = 0.033$) in ice hockey than in all other surveyed sports combined (Table 7).

In floorball, two patients had lowered final visual acuity, the first patient had a visual acuity of 0.12, contusion, operated retinal ablation and a post-operative macular pucker. The second

Table 5. Final status and future risk estimate of sports-related eye injury patients.

Sport	Injuries *n*	Need for lifelong follow-up		Need for surgical operation in the future		Permanent functional impairment	
		n	%	*n*	%	*n*	%
Floorball	47	43	91	2	4	3	6
Football	19	12	63	1	5	1	5
Tennis	15	14	93	1	7	2	13
Ice hockey	12	10	83	1	8	4	33
Cycling	8	1	13	1	13	1	13
Badminton	7	6	86	1	14	2	29
Basketball	6	2	33	0	0	0	0
Baseball	6	4	67	0	0	0	0
Combat sports	6	2	33	0	0	0	0
Gymnastics	4	3	75	0	0	1	25
Rink bandy	3	3	100	0	0	0	0
Cross-country skiing	3	2	67	0	0	1	33
Orienteering	2	0	0	0	0	0	0
Gym	2	1	50	0	0	0	0
Other	9	5	56	0	0	2	22
Total	149	108	72	7	5	17	11

Table 6. OTS, permanent functional impairment* and sport distribution of sports-related eye injuries.

	OTS					
Sport	1	2	3	4	5	Not classifiable
Floorball	0	1	5 (2)	2	38 (1)	1
Football	0	0	0	0	18 (1)	1
Tennis	0	0	1	5 (1)	9 (1)	0
Ice hockey	0	1 (1)	3 (1)	1 (1)	6 (1)	1
Basketball	0	0	0	0	6	0
Cycling	0	0	0	1 (1)	6	1
Badminton	0	1 (1)	1 (1)	0	5	0
Baseball	0	0	0	0	6	0
Combat sports	0	0	0	0	6	0
Rink bandy	0	0	1	0	2	0
Cross-country skiing	0	0	0	1 (1)	2	0
Orienteering	0	0	0	0	2	0
Gymnastics	0	0	0	0	4 (1)	0
Gym	0	0	0	0	2	0
Other	0	0	2 (1)	0	7 (1)	0
Total	0	3 (2)	13 (5)	10 (4)	119 (6)	4

* The number of patients who had permanent impairments were reported in brackets in each group. If no value was reported, the value was zero.

Table 7. Permanent impairment in ice hockey compared to other sports.

Sport	Permanent impairment, *n* (%)	No permanent impairment, *n* (%)	p*
Ice hockey	4 (33)	8 (67)	0.033
Other sports	13 (9)	124 (91)	

*Fisher's exact test.

patient had a visual acuity of 0.5, contusion, operated retinal ablation, trauma-induced glaucoma needing permanent medication and a postoperative cataract. A third patient had functional impairment due to a permanently extreme wide pupil, causing glare due to a contusion and an anterior chamber angle defect.

In badminton, two patients had lowered final visual acuity. The first had a visual acuity of 0.16, contusion, operated retinal ablation and incipient cataract. The second had a visual acuity of 0.8, visual field defect, contusion and optical nerve injury.

In tennis, two patients had lowered final visual acuity. The first had a visual acuity of 0.5, worsened night vision after contusion and a twice laser-operated retinal tear. The second had a visual acuity of 0.6, contusion, incipient cataract and vitreous prolapse.

In F1 motorboat sport, one patient had lowered quality of central vision due to a contusion and macular haemorrhage. In skiing, one patient had lowered quality of central vision due to a corneal scar from a penetrating injury. In mix-match floorball-golf (floorball stick, golf ball), one patient had functional impairment due to a permanently extreme wide pupil causing glare due to a contusion, in addition to an unoperated orbital fracture, a laser-operated retinal tear, an operated lid trauma and a trauma-induced glaucoma needing permanent medication. In football, trampoline gymnastics and cycling, one patient in each sport had double vision in upward gaze, caused by an operated orbital fracture; the cycling patient had, in addition, a penetrating orbital wound and a foreign body, an operated lid and lacrimal wound and a contusion.

Classified by OTS, there were no cases in class 1; 3 in class 2; 13 in class 3; 10 in class 4; and 119 cases in class 5. The OTS scores and permanent disability in different sports are shown in Table 6. Four cases were not classifiable due to missing visual acuity in the first clinical visit. None of these unclassified cases was clinically estimated to have caused permanent functional visual impairment.

Table 8. Incidence rates period* 2011–12 compared to 2002–03.

	IR (95% CI)		IR (95% CI)		
Sport	Period 2011–12		Period 2002–03		p
Floorball	0.55	0.37–0.80	0.92	0.67–1.25	0.03
Football	0.20	0.09–0.36	0.16	0.07–0.31	0.62
Tennis	0.56	0.26–1.07	0.43	0.16–0.93	0.60
Ice hockey	0.32	0.14–0.60	0.19	0.06–0.45	0.37
Badminton	0.20	0.07–0.48	0.37	0.16–0.73	0.28
Combat sports	0.25	0.05–0.73	0.53	0.15–1.37	0.31
Rink bandy	0.67	0.08–2.41	0.78	0.31–1.60	0.85

* Based on 6-months of data.

The change in eye trauma incidence in different sports in Finland

The incidence data were available for seven sports in 2002–03 and 2012–13. Statistically compared to previous data, the number of eye injuries has significantly declined ($p = 0.035$) in floorball. In football, tennis, ice hockey, badminton, combat sports and rink bandy, the incidence changes were not statistically significant (Table 8).

Protective eyewear

Seven (5%) patients were using protective eyewear. Four were using an eye mask in ice hockey, where one-third (4/12) of the injuries incurred in spite of the visor. Two traumas were caused by a puck coming under the visor and two by a stick slipping under the visor. In one of the latter cases, the opponent player was given a high-sticking penalty. In floorball, two patients and, in F1 motorboat sport, one patient were using protective eye goggles. Two traumas in ice hockey, one in floorball and one in F1 motorboat sport were

estimated to cause permanent functional impairment in spite of protective eyewear use. However, none of these traumas was penetrating. All patients were adults.

Forty-one percent of patients were willing to use protective eyewear in the future. The data were not available in 49/149 cases.

Of the more than 50 countries belonging to the IFF (International Floorball Federation), only Finland has made protective eyewear mandatory in gradually increasing age groups in junior floorball. In the future, protective eyewear will be mandatory in Finnish official floorball in all age groups under 18 years of age. In the current study period, protective eyewear was mandatory in the under-14 age group. In the current study (6-month time period), the number of floorball eye injuries in the under-14 age group was one compared to 11 in the previously published study (2002–03, in an equal 6-month time period) (Leivo et al. 2007); the sole floorball eye injury in the under-14 age group was incurred during a non-organised practice.

Discussion

This study presents in detail the epidemiologies, clinical statuses, diagnoses, treatments, use of resources and outcomes of sports-related eye trauma in different sports. Based on the results, we are able to give evidence-based recommendations for the use of protective eyewear in sports.

The strength of the study is the excellent coverage of new eye injuries in a single referral centre, whose population base is 1.5 million people. The study population does not include minor eye trauma, which is treated in health centres or occupational primary care. One additional, small, non-emergency, secondary care eye unit exists in the area, and during office hours has treated sporadic minor eye trauma not needing surgical care that is not included in the study. Unlikely but possible, is that single, critically ill, intensive care and unmovable patients may have been treated at the university general trauma hospital and would not have been included in this study. However, due to the division of labour and surgical facilities, these patients are, in principal, referred to the university eye clinic and thus included in the study.

The weakness of the study is the short, 3-month follow-up. Additionally, in minor trauma cases, some of the follow-ups were referred to care facilities outside of the university clinic. However, imminent visual impairment is normally detected within a 3-month period, and we reported the estimated need for long-term follow-up and further eye surgery. Nevertheless, many eye injuries carry a long-term risk of visual impairment, which can be diagnosed only several years or decades after the incident. There is a need for long-term studies on ocular injuries.

The questionnaire concerning epidemiological and circumstantial data was filled out by 72% of the patients. The emergency care personnel was busy and did not always remember to handout the questionnaire; only one patient declined to fill out the questionnaire. Nevertheless, when available, these data were obtained from the patient records.

Floorball is the leading eye-injury-causing sport in Finland, accounting for 32% of all eye injuries in sports. Studies from Nordic and central European countries, where floorball is popular, have also reported floorball to be a major eye-injury-causing sport (Ghosh & Bauer 1995; Drolsum 1999; Maxen et al. 2011). In our study, football, tennis and ice hockey were the next most common sports causing eye injuries. In relation to the sport participation rate, rink bandy, floorball and tennis caused the most eye injuries. Contrary to other mainstream sports, where eye injuries were most common in the 10–19 age groups, in floorball, eye injuries were most common in the 40–49 age groups, probably due to the fact that, compared to younger age groups, very few floorball players in this age group use protective goggles. The distribution of different sport types causing ocular injuries reflects the popularity, dangerousness and the protective eyewear culture in the sport type.

In general, the popularity of different sport types and sports varies internationally. In the United States, for example, the most common eye-injury-causing sports are baseball and softball, basketball, racquetball, soccer (European football) and American football (Cass 2012). Kim et al. (2011) have reported US ocular sport injury incidences based on the national injury database system, a stratified probability sample of 100 hospital emergency departments in the United States and National Sporting Goods Association data. In the most popular sports, our yearly incidence rates per 1000 participants are higher, for instance, in European football (0.19 versus 0.109), tennis (0.48 versus 0.077), ice hockey (0.21 versus 0.015) and basketball (0.38 versus 0.216). Unlike our study, Kim et al.'s data are based on a stratified sample from an injury register, not individual health records. Kim et al. discuss several data and statistical reasons, which result in their underestimation of incidences. However, the differences, especially in ice hockey and tennis, are noteworthy.

Contusion was the primary diagnosis in 77% of eye injuries. Although closed globe injuries carry a better prognosis than open globe injuries, the diagnosis of contusion implies serious consequences for many patients. Nine percent of contusion patients had potentially vision-threatening retinal macular oedema. Thirty two percent of contusion patients had clinically significant secondary diagnoses, including: retinal tear, retinal haemorrhage, lid or lacrimal wound, vitreous haemorrhage and retinal detachment, optical nerve injury, trauma cataract, non-penetrating scleral tear, choroidal tear, vitreous prolapse, vitreous opacification and posterior vitreous detachment. Many of these severe diagnoses should have been coded as the primary diagnosis, but the current WHO ICD-10 diagnosis coding system is missing ocular trauma codes (S- and T-codes), especially concerning retinal ocular trauma, and should be reconsidered. In our study, 13 of 17 patients who incurred permanent visual impairment had contusion as the main diagnosis.

In addition to severe secondary diagnosis, the majority of contusion patients need lifelong follow-up due to increased glaucoma risk. We estimated that 107 of 119 contusion patients (including contusion as primary or secondary diagnosis) needed lifelong follow-up. A 3–4% incidence of glaucoma after ocular contusion has been reported in a 6-month follow-up, and up to 10% in a 10-year follow-up (Kaufman & Tolpin 1974; Girkin et al. 2005).

It is noteworthy that in three cases, functional visual impairment was

caused by double vision after operated orbital fracture. However, the double vision was consistently in non-direct gaze. Fifty percent of operated orbital fracture patients had postoperative double vision. This can be due to statistically small numbers, severe trauma or surgical technique.

Floorball eye injuries in the under-14 age group declined in a 9-year interval (season 2002–03 to 2011–12) from 11 to 1 (in an equal 6-month period). This result is a direct consequence of the Finnish Floorball Federation's decision to enforce protective eyewear mandatory in this age group.

In official Finnish ice hockey, visor-use is mandatory in all age groups where a full mask is not worn and has been mandatory in gradually increasing age groups for 30 years. Half of our reported cases occurred in unofficial practice. Ice hockey eye injuries are on the rise and relatively severe, and a third of these injuries occurred despite visor use. However, no penetrating injuries were observed. A visor can effectively prevent eye trauma only when fitted and used correctly, that is worn and positioned to cover the eyes and the lower edge of the nose in all projections.

Our study demonstrates that protective eyewear in junior floorball is effective in preventing eye injuries and should be mandatory in all age groups. In ice hockey, the proper use of a visor should be emphasised and visor-use in non-organised practice should be encouraged.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Clinical findings of sports-related eye injuries in the first visit.

ORIGINAL PUBLICATIONS

II

PAEDIATRIC EYE INJURIES IN FINLAND. HELSINKI EYE TRAUMA STUDY.

Acta Ophthalmologica

Acta Ophthalmologica 2017

Paediatric eye injuries in Finland – Helsinki eye trauma study

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ABSTRACT.

Purpose: **To determine the current population-based epidemiology, treatment, use of resources and outcomes of children's eye injuries in Finland.**

Methods: **The study included all new patients, 16 years of age or under, with ocular or orbital traumas taken into care to the Helsinki University Eye Hospital (population base 1.5 million people) in 1 year. The follow-up period was 3 months.**

Results: **Two hundred and two children's eye injuries were treated. The eye injury incidence was 5.2–8.3 per 10 000 per year, including all minor and major eye traumas. Eye injury most likely occurred at the junior high school age (13–16 years). Thirty-three percentage of accidents took place at home and 24% at school or in day care. The most common causes were sports equipment (15%), contact with human body (12%) and superficial foreign bodies (11%). Excluding minor injuries, contusion was the most common diagnosis (n = 60, 30%). Eighty-seven percentage of contusion patients were estimated to need lifelong follow-up due to elevated glaucoma risk. Nine percentage of all patients had a permanent disability. Guns, fireworks, tools and pellet guns were relatively the most dangerous objects. Pellet guns caused 6% of eye injuries, 36% of them causing permanent impairment. The number of outpatient visits was altogether 443, inpatient days were 49, and 60 children had major surgeries.**

Conclusions: **Use of protective eyewear would have prevented or diminished eye traumas caused by pellet gun, floorball, most of the firework and in many superficial foreign body. The use of pellet guns and protective eyewear should be more supervised. Fireworks and tools are not suitable toys for children.**

Key words: epidemiology – eye injury – firework – outcome – paediatric – pellet gun

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Introduction

Eye injury is a common cause of decreased vision, visual loss and morbidity in children (Strahlman et al. 1990; McEwen et al. 1999; Bunting et al. 2013; Lesniak et al. 2012). Incidence of paediatric eye trauma has been reported to be 8.9–15.2/100 000 per year in the paediatric age group (Strahlman et al. 1990; McEwen et al. 1999). Major causes of traumas have been accidental blows and falls, sports equipment and items used to poke or throw. About 62–65% of hospitalized paediatric trauma patients have had blunt ocular trauma and 16–28% were shown to be open-globe trauma (Strahlman et al. 1990; McEwen et al. 1999; Thompson et al. 2002).

Many previous studies that report children's ocular trauma are limited, for instance, by a single, or specific cause, diagnosis or a too restricted age group. Serious traumas, such as open-globe trauma and traumatic cataract, are often of more interest (Thompson et al. 2002; Sarrazin et al. 2004; Tok et al. 2011; Chen et al. 2013; SooHoo et al. 2013). Finnish data are available for the sports- or firework-related eye injuries, but other epidemiological data is from 1981 (Niiranen & Raivio 1981; Leivo et al. 2007; Kivelä 2014).

This study aimed to determine the population-based current epidemiology of children's eye injuries in rural and urban southern Finland comprehensively with a specific interest in the causes and consequences of these injuries. This study analyses the findings, treatments, use of resources and outcome of paediatric eye injury patients in a 1-year period.

Materials and Methods

The study was approved by the ethics committee of the Helsinki-Uusimaa Hospital District and followed the tents of the Declaration of Helsinki. An informed consent was obtained from the patients or their caregivers. The data was collected from all the patients with eye injury taken into care at the Emergency Clinic of the Helsinki University Eye Hospital (HUEH) during a 1-year period between 1 May 2011 and 30 April 2012. The HUEH is the tertiary and secondary care eye hospital, with a population base of 1.5 million. This study included all new paediatric patients (16 years of age or under).

To obtain full coverage of the data, first, the patients or their caregivers were prospectively identified in the

emergency clinic and were requested to fill out the questionnaire. Secondly, using ICD-10 diagnoses indicating eye injury directly or indirectly, the relevant hospital records were accessed in order to find any possible missed patients. Also occasionally, in clinical practice, incorrectly used 'non-trauma' diagnoses were searched. Thirdly, the researchers examined all the case histories and confirmed the accuracy of the injury details.

A patient questionnaire inquired about the circumstances and causes of the accident, use of protective eyewear, influence of alcohol and whether the injury was intentional. In the absence of the questionnaire, the information was gathered from the hospital records. Additional information, including the involved eye (left, right or both), age, sex, possible amblyopia, detailed findings at the first visit, diagnoses and anatomical location of the injury, was recorded from the hospital records.

The injuries were categorized based on the primary diagnoses and possible secondary and tertiary diagnoses were recorded. Clinically, the most significant ocular trauma-associated ICD-10 S- or T-diagnosis and/or the one needing most healthcare resources was chosen as the primary diagnose. Other diagnoses were secondary or tertiary. Injury categories included the following diagnosis groups: contusions, open-globe traumas (OGTs), lid or lacrimal wounds, orbital fractures, chemical or thermal burn injuries and other mild injuries. If both eyes were injured, the more seriously injured eye was observed. The epidemiological data was analysed and the distributions were represented. The percentages were calculated from the reported results. The yearly incidence of eye injuries for each age group was calculated. Causes of ocular trauma by primary diagnosis group are presented. Clinically, the most significant status findings by each anatomical location are reported in different diagnosis groups.

The resource use measures were the number of outpatient visits, the number of hospitalization, medication and sports activity restriction days and the number of operations and general anaesthesia. If the sports restriction was not recorded in the patient data, the restriction need was estimated based on international recommendations and the individual clinical status findings (Gerstenblith & Rabinowitz 2012; Recchia et al. 2002; Tsai et al. 2011; Walton et al. 2002). Birmingham Eye Trauma Terminology System (BETTS) and Ocular Trauma Score (OTS) grading were subsequently applied to the data (Kuhn et al. 2002, 2004).

The follow-up time was 3 months. At the time of the last visit, the final visual acuity, the intraocular pressure and the main abnormal status findings were recorded. The severity of the eye trauma was evaluated using OTS rating, the estimated need for lifelong follow-up, performed major surgery and future surgery, and permanent disability due to abnormal visual acuity or other symptoms. The end-points compared to cause, diagnosis group and OTS are presented.

The year was divided into four seasons: spring (March, April, May), summer (June, July, August), autumn (September, October, November) and winter (December, January, February) because some trauma-causing activities in Finland are seasonal.

Shaken-baby patients who are exceptionally treated in the Helsinki University Children's Hospital were not included in the study.

Results

Background information

Two hundred and two children aged 6 weeks to 16 years, 18% of all new eye traumas (1151), were treated in the Helsinki University Eye Hospital during a period of 1 year. The questionnaire was obtained from 112 (55%) of the patients or their caregivers. Seventy-eight patients (39%) were found based on ICD-10 trauma diagnosis and twelve (6%) on non-trauma diagnosis. The eye injury was most likely at the age of junior high school (years 13–16, 8.3/10 000) (Fig. 1). The distribution of primary diagnoses in different age groups is shown in Fig. 2. In older age groups, the amount of contusions is higher and OGTs and orbital fractures are missing from the youngest age group. Males were affected in 74% of accidents. One hundred and five (52%) of traumas were in the left eye, 93 (46%) in the right eye and 4 (2%) were bilateral. Five eyes were amblyopic.

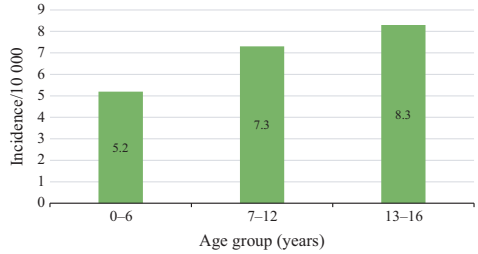

Fig. 1. Incidence of eye injuries in different age groups.

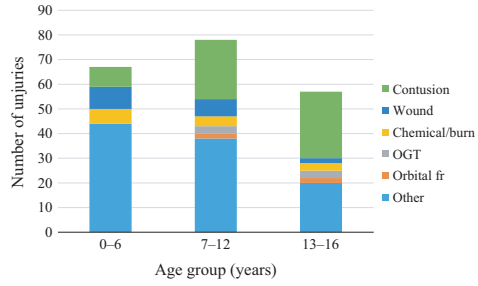

Fig. 2. Distribution of eye injury types in different age groups. OGT = open-globe trauma, orbital fr = orbital fracture, other = corneal abrasion or superficial foreign body, superficial contusion in eyelid or periocular area.

Data on the location of injury was available in 145 (72%) of cases. Most of the injuries 67 (46%) took place at home, of which 35 (24%) took place outside and 32 (22%) inside. Fifty (34%) of the injuries took place at school or in day care, eleven (8%) at sports sites and six (4%) in the forest or at other outdoor sites. 29% occurred in spring, 27% in autumn and 22% in winter and summer. There were five assaults. In two cases, one injured child (15 years of age) and one assaulter were reported to be under influence of alcohol. Four (3%) of eye traumas were traffic related and 38 (19%) of injuries were related to sports.

The causes of the eye injuries are shown in Table 1. Sports equipment caused 31 (15%) of the injuries, including 24 contusions and one OGT was from a ski pole. Contact with a human body caused 25 (12%) injuries, including four contusions and three orbital fractures: an assault, one injury in gymnastics and one in trampoline jumping.

Superficial foreign bodies (FB) caused 22 (11%), toys 16 (8%) and sticks and branches 15 (7%) of the ocular traumas. Pellet guns caused 12 (6%) of the traumas, including 10 contusions. Eight (4%), injuries were caused by chemicals; detergents (3), concrete, streamlining dust, instant glue, nail glue and an exploded spray bottle. Animals caused seven (3%) injuries, including four wounds by dog bites.

Fireworks caused four (2%) eye traumas, including two OGTs: a rocket that was lit in the hand and exploded at a distance of 1–2 m and a shell-like firework which slipped from hand. A dropping firework stick caused contusion and cataract to a bystander. A homemade firework made mainly from foil and alkaline detergent caused a chemical trauma.

Tools caused three injuries, including two OGTs caused by a shot from a nail gun and a thrown nail. An air gun loaded with a matchstick caused a single OGT. A collision with the ice floor caused orbital fracture.

Primary and secondary diagnoses, initial clinical findings and surgical treatments

Status findings at the first visit are represented in Table 2 and trauma categorizations according to BETTS is given in Fig. 3 (Kuhn et al. 2004). According to BETTS, the total traumas are comprised of six open-globe and 62 closed-globe traumas.

Contusions

Contusion was the primary diagnosis in 60 (30%) cases and the secondary diagnose in one orbital fracture. Twenty-eight (47%) contusion patients had retinal or choroidal findings: peripheral oedema (14), retinal haemorrhages (6), macular oedema (3), retinal tears (2), retinal detachments (2) and choroidal rupture (1). Two patients had orbital fractures. For seven (12%) patients, ten major operations were performed: six retinal, two cataract and two lid surgeries.

Wounds

Lid wound was the primary diagnosis in 18 (9%) cases. In three (17%) cases, the canaliculus was lacerated. Thirteen patients needed surgical repair. One previously sutured infected wound was reoperated. Lid wound was a secondary diagnosis in 14 (7%) of eye traumas.

Chemical and thermal injuries

Chemical and thermal injury were the primary diagnosis in 13 (6%) patients, including five alkali and none acid injuries. Except a patient injured from a self-made firework with ischaemic areas in the conjunctiva, all injuries were mild.

Open-globe traumas

Open-globe trauma was the primary diagnosis in six patients, including four penetrating and two combined injuries (Fig. 3). Initial VA was from NLP to 20/40. An air gun loaded with matchsticks caused a zone 2 limbus to limbus wound and severe intraocular damage, needing a primary suturation, vitrectomy and eventually evisceration. A nail gun shot caused zone 3 OGT, needing five operations and probable further vitreoretinal surgery. A rocket-type firework caused sutured corneal zone 1 wound. A shell-type firework caused sutured sclerocorneal (zone 2) and an eyelid wounds. A thrown nail caused sclerocorneal wound (zone 2), needing suturation, and a later-observed retinal tear treated with a laser. A trauma from a ski pole caused zone 1 corneal wound, which was treated with a contact lens.

Orbital fractures

Four (2%) patients had an orbital fracture as a primary diagnosis. Three needed surgical repair of the orbital floor. The delay for the surgery was one, two and seventeen days. Orbital fracture was the secondary diagnosis in two patients, contusion being the primary diagnosis. Neither of these needed surgical treatment.

Other diagnoses

In 101 (50%) patients, the eye injury was considered minor: 67 (66%) abrasions, 19 (19%) corneal superficial foreign bodies, seven (7%) in conjunctiva and

Table 1. Causes of ocular trauma by primary diagnosis groups.

Cause	ALL	Contusion	Wound	Chemical	OGT	Orbital fr	Other*
Sports equipment	31	24	1	–	1	–	5
Body part	25	4	1	–	–	3	17
Superficial FB	22	–	–	–	–	–	22
Toys	16	2	1	–	–	–	13
Sticks	15	6	2	–	–	–	7
Pellet guns	12	10	–	–	–	–	2
Chemicals	8	–	–	8	–	–	–
Animals	7	–	4	–	–	–	3
Fireworks	4	1	–	1	2	–	–
Pens/pencils	4	–	1	–	–	–	3
Thermal injury	4	–	–	4	–	–	–
Tools	3	–	–	–	2	–	1
Gun	1	–	–	–	1	–	–
Other	50	13	8	–	–	1	28
All	202	60	18	13	6	4	101

OGT = open-globe trauma, superficial FB = superficial foreign body.
* Corneal abrasion or superficial foreign body, superficial contusion in eyelid or periocular area.

Table 2. Clinical findings at the first visit by primary diagnose groups.

Clinical findings		ALL	Contusion	Wound	Chemical	OGT	Orbital fr	Other
All		202	60	18	13	6	4	101
VA	≥20/25	101	26	6	9	–	3	57
	20/40-19/25	29	11	3	–	1	–	14
	20/200-20/50	22	12	1	–	1	1	7
	1/200-19/200	8	5	–	–	2	–	1
	LP/HM	4	3	1*	–	–	–	–
	NLP	2	–	–	–	2	–	–
	No data	36	2	7	4	–	–	23
TA	>21 mmHg	21	15	–	1	–	–	5
Eyelids	Normal	132	39	–	10	4	1	78
	Wound	18	2	15	–	1	–	–
	Minor wound	14	4	3	1	1	1	4
	Other	38	15	–	2	–	2	19
Conjunctiva	Normal	49	12	8	3	2	2	23
	Subconj. hem	142	47	8	9	3	2	72
	Wound	9	1	2	–	1	–	5
	Other	2	–	–	1	–	–	1
Cornea	Normal	106	31	16	6	–	4	49
	Abrasion	74	20	2	7	–	–	45
	Penetrating tr	6	–	–	–	6	–	–
	Other	16	9	–	–	–	–	7
Anterior	Normal	142	8	18	12	–	4	100
Chamber	Microhyphema	14	13	–	–	1	–	–
	Macrohyphema	23	21	–	–	2	–	–
	Cell reaction	19	17	–	1	–	–	1†
	Other	4	1	–	–	3	–	–
Iris	Normal	179	43	18	13	2	4	99
	Dilated Pupil	2	2	–	–	–	–	–
	Rupture	4	3	–	–	1	–	–
	Other	17	12	–	–	3	–	2
Lens	Normal	199	59	18	13	4	4	101
	Other	3	1	–	–	2	–	–
Vitreous	Normal	194	55	18	13	3	4	101
	Blood cells	5	5	–	–	–		–
	Other	3	–	–	–	3	–	–
Retina	Normal	169	32	18	13	1	4	101
	Tear	7	4	–	–	3	–	–
	Macular Oedema	3	3	–	–	–	–	–
	Peripheral Oed	16	14	–	–	2	–	–
	Haemorrhage	6	6	–	–	–	–	–
	Chor. rupture	1	1	–	–	–	–	–
Orbita	Normal	196	58	18	13	6	–	101
	Fracture	6	2	–	–	–	4	–

VA = visual acuity, OGT = open-globe trauma, Orbital fr. = orbital fracture, LP/HM = light perception/hand movement, NLP = no light perception, Subconj. hem = subconjunctival haemorrhage, penetrating tr = penetrating trauma, peripheral Oed = Peripheral oedema, Chor. rupture = Choroidal rupture.

* Amblyopic schoolgirl;

† Due to erosion. Most severe finding recorded in each anatomical site.

eight (8%) superficial contusions in the eyelid or periocular area.

The information on protective eyewear wearing was from all sports equipment-, pellet gun-, tool- and firework-caused traumas and in total of 111 (54%) of patients. Despite the use of protective eyewear, three patients were injured: a firework stick caused contusion and traumatic cataract, a pellet gun a contusion and permanently dilated pupil without subjective harm, and welding activity a metallic foreign body to the cornea.

Resource use

The use of resources is presented in Table 3. One hundred and eighty-five (92%) patients were treated in the outpatient ward. The total number of outpatient visits was 443 and inpatient days were 49. One hundred and seventy-seven (88%) children needed medication, including two who needed medication after the 3-month follow-up period. One hundred and forty-five (72%) needed activity restriction.

Sixty operations were performed for 46 (23%) children: 40 major and 20 minor surgeries. Forty-three (72%) operations needed general anaesthesia. Six patients were estimated to need future operations: three cataract and one vitreoretinal surgery and two suture removals.

Outcomes of injuries

Permanent functional impairment, need for lifelong follow-up, final VA and major surgeries by the type of

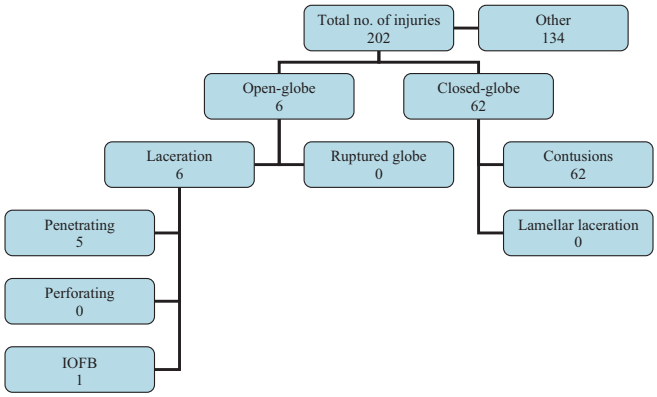

Fig. 3. Distribution of the injuries according to BETTS. Group 'other' includes eyelid wounds (18), orbital fractures (4) and non-severe eye traumas (corneal abrasions, superficial foreign bodies, and superficial contusions in eyelid or periocular areas) that are not included in BETTS. BETTS = Birmingham Eye Trauma Terminology System, IOFB = Intraocular foreign body.

Table 3. Resource use, treatment and activity restriction.

Resources	No. of patients	Average mean/ involved patients	Range/involved patients	Total no. of resource unit used
Outpatient visits	202	2.2	1–12	443
Outpatient visits after 3 months	27	1.7	1–4	45
Hospitalization (days)	17	2.9	1–10	49
Medication, duration (days)	177	11.1	1–90	1966
Major surgeries	28	1.6	1–5	40
Minor procedures*	18	1	1–2	20
Need for general anaesthesia	31	1.4	1–5	43
Activity restriction (days)	145	33.8	2–90	2226

* Foreign body removal from cornea, examination in general anaesthesia.

Table 4. End-points compared to diagnose group.

	No. of traumas	Permanent disability	Need for lifelong follow-up	Final VA <20/25	Major surgeries*
Contusion	60	9 (15%)	52 (87%)	4 (7%)	7 (12%)
Wound	18	1 (6%)	–	–	13 (72%)
Chemical	13	–	–	–	–
OGT	6	6 (100%)	6 (100%)	6 (100%)	5 (83%)
Orbital fr	4	3 (75%)	–	–	3 (75%)
Other†	101	–	–	–	–
All	202	19 (9%)	58 (29%)	10 (5%)	28 (14%)

VA = visual acuity, OGT = open-globe trauma, Orbital fr = orbital fracture.
* Number of patients;
† Corneal abrasion or superficial foreign body, superficial contusion in eyelid or periocular area.

injury causes are shown in Table 4. There were no serious bilateral eye injuries.

Nineteen (9%) children were estimated to have a permanent disability and 58 (29%) need a subsequent lifelong follow-up. Twenty-eight (14%) needed major surgeries in the 3-month follow-up (Table 4). Two patients, one with chemical trauma from fireworks and one with pellet gun-caused macular oedema, were lost in the follow-up and possibly have permanent disability.

Nine (15%) children with contusion had permanent disability. Lowered VA less than 20/25 was found in four patients, caused by pellet gun, hockey stick, toy sword and a hit. Amblyopia treatment was started in cases of young children: a pellet gun-caused retinal detachment was treated with a plomb which induced astigmatism and in other case firework caused traumatic cataract. Two children lacked accommodation due to IOL implantation caused by fireworks and a pellet gun. Three children had severe glare because of iridodialysis caused by pellet guns, and one had a permanently dilated pupil. Fifty-two contusion patients (87%) were estimated to need lifelong follow-up because of elevated glaucoma risk (Table 4).

One patient had facial wounds and a facial nerve injury after a car accident. All three operated, lacrimal canalicular trauma patients had a normal status in the follow-up (Table 4). In chemical traumas, there were no permanent disabilities. A patient with injury from a self-made firework was lost in the follow-up (Table 4).

All patients with OGT had permanent disability and a final VA less than 20/25. One patient had an evisceration caused by an air gun shot and one patient VA of light perception caused by a nail gun shot. All children with OGT were estimated to need lifelong follow-up because of the tissue damage and in order to ensure the health of the contralateral eye (Table 4).

All three (75%) operated orbital fracture patients had double vision in upward gaze. Traumas were caused in trampoline jumping, by an assault and by a kick in school activity (Table 4).

Table 5 shows permanent disability, need for lifelong follow-up, final VA and major surgeries according to cause. The main causes for permanent disability were a hit from a body part (4), pellet guns (4), sports equipment (3) and fireworks (3). Two of the three tool-caused traumas caused permanent disabilities. The main reasons for the need for lifelong follow-up were sports equipment (21), pellet guns (10) and sticks (6).

The OTS classification by primary diagnosis groups is shown in Table 6. Altogether, nine patients were lost in

Table 5. End-points compared to cause.

	No. of traumas	Permanent disability	Need for lifelong follow-up	Final VA <20/25	Major surgeries
Sports equip.	31	3 (10%)	21 (68%)	2 (6%)	4 (13%)
Body part	25	4 (16%)	1 (4%)	1 (4%)	4 (16%)
Superficial FB	22	–	–	–	–
Toys	16	1 (6%)	2 (13%)	1 (6%)	1 (6%)
Sticks	15	–	6 (40%)	–	1 (7%)
Pellet guns	12	4 (33%)	10 (83%)	1 (8%)	2 (17%)
Chemicals	8	–	–	–	–
Animals	7	–	–	–	3 (43%)
Fireworks	4	3 (75%)	3 (75%)	2 (50%)	3 (75%)
Pens/pencils	4	–	–	–	1 (25%)
Burn	4	–	–	–	–
Tools	3	2 (67%)	2 (67%)	2 (67%)	2 (67%)
Gun	1	1 (100%)	1 (100%)	1 (100%)	1 (100%)
Other	50	1 (2%)	12 (24%)	–	6 (12%)
All	202	19 (9%)	58 (29%)	10 (5%)	28 (14%)

VA = visual acuity, Sports equip. = sports equipment, superficial FB = superficial foreign bodies.

Table 6. OTS rating, permanent disability and lowered visual acuity in primary diagnose groups.

OTS	1	2	3	4	5	N/a	All
Contusion	–	2	11	7	37	3	60
PD	–	2	5	–	–	1	9
LVA	–	2	1	1	–	1	4
Wound	–	–	1*	1	9	7	18
PD	–	–	–	–	1	–	1
LVA	–	–	–	–	–	–	–
Chemical	–	–	–	–	9	4	13
PD	–	–	–	–	–	–	–
LVA	–	–	–	–	–	–	–
Orbital fracture	–	–	1	–	3	–	4
PD	–	–	1	–	2	–	3
LVA	–	–	–	–	–	–	–
OGT	2	2	1	1	–	–	6
PD	2	2	1	1	–	–	6
LVA	2	2	1	1	–	–	6
Other†	–	–	1	6	69	25	98
PD	–	–	–	–	–	–	–
LVA	–	–	–	–	–	–	–
All	2	4	15	15	127	39	202
(PD/LVA)	(2/2)	(4/4)	(7/2)	(2/1)	(3/0)	(1/1)	(19/10)

PD = Permanent disability, LVA = lowered visual acuity, OGT = open globe trauma, OTS = Ocular Trauma Score.
* Amblyopic schoolgirl syndrome.
† Corneal abrasion or superficial foreign body, superficial contusion in eyelid or periocular area.

the follow-up period. OTS rating was gathered from 163 children. Other patients were either too young to estimate the VA for OTS, or the trauma did not involve the eye globe. All six patients with OTS grading 1 or 2 were defined as permanently disabled after the three-month follow-up period.

Discussion

This comprehensive population-based study highlights the diversity of eye injuries in children. The total amount of 202 paediatric patients covers all new minor and major (tertiary and secondary care) eye injuries, which were treated in the Helsinki University Eye Hospital covering a population of 1.5 million inhabitants. Some of the most minor injuries may have been treated in healthcare centres or private healthcare facilities and are not included in this study, although the true number of all minor eye injuries such as superficial foreign bodies might be higher. To our knowledge, this is the first longitudinal study examining eye traumas in a 1-year period in Finland. This study reports the epidemiology, clinical findings, diagnoses, treatments, resource use and outcomes and gives essential causal connection-based data from children's eye injuries.

Compared with previous studies by Lesniak et al. (2012), Strahlman et al. (1990) and McEwen et al. (1999), the incidence of eye traumas in our study 5.2–8.3 per 10 000 per year was high compared with 8.9–15.2 per 100 000 per year in paediatric patients. Our study includes also minor traumas, which explains the difference. It is well known that ocular traumas are more common in males. Males tend to be more active in sports, and sports equipment was the primary cause of ocular trauma (Strahlman et al. 1990; McEwen et al. 1999; Leivo et al. 2007). According to Abbott & Shah (2013), the incidence of eye trauma is higher among children over the age of 12 and similar results were also found in our study.

There are few limitations in our study. First, the 3-month follow-up is relatively short. Treating amblyopia may result in better VAs after 3 months. In contusions, eye pressure may elevate even after several years and far-reaching consequences may thus not be seen in this study. In six children, future operations were scheduled, and, for example, corneal suture removal may affect the VA. Nevertheless, obvious permanent disabilities are seen in a 3-month period. We lacked the information of the protective eye-wear use from 45% of patients but had the information of relevant traumas (sport equipment, pellet gun, firework and tools). The nature of eye trauma is often accidental, and that is why the use of protective eye-wear is not often an issue.

One hundred and thirty-four (66%) of traumas could not be categorized in BETTS, including eighteen lid wounds, four orbital fractures and other non-severe eye traumas. This may jeopardize further trauma studies using solely BETTS classification. BETTS could be adjusted by having three, instead of two major subclasses: open-globe, closed-globe and adnexal trauma, including orbital fractures and eyelid or lacrimal wounds. Closed-globe traumas could be adjusted by one more

subclass, superficial eye traumas. In one non-severe trauma, the injury was diagnosed as a contusion according to BETTS, because of the trauma mechanism and depression in sclera. However, no other findings made it appropriate to have contusion as a primary diagnosis (Kuhn et al. 2004).

In our study, during a 1-year period, 19 (9%) children were permanently injured due to ocular trauma; permanent disabilities included nine contusions: six OGTs, three orbital fractures and one wound. Incidence of traumatic paediatric cataract requiring treatment has been reported to be 5 per million in 1 year in Australia (Staffieri et al. 2010). In our study, it was 7 per million. Absence of rebleeding in traumatic hyphema may be explained with Scandinavian White race (Walton et al. 2002; Girkin et al. 2005; SooHoo et al. 2013). No OGTs were caused from blunt ocular trauma. This is in accordance with a previous study concerning paediatric retinal detachment and confirms that children's more elastic and smaller globe and face may be a protective factor (Sarrazin et al. 2004).

Contusion and OGT caused the need for lifelong follow-up. Altogether, 58 (29%) of all eye-injured children need a yearly eye examination for the rest of their lives, primarily because of the elevated risk for glaucoma after contusion. A 3–4% incidence of glaucoma after ocular contusion has been reported in a 6-month follow-up, and up to 10% in a 10-year follow-up (Kaufman & Tolpin 1974; Walton et al. 2002; Girkin et al. 2005).

Sports equipment was the major cause for eye injuries (15%) and the same has been observed in previous studies (Strahlman et al. 1990; McEwen et al. 1999; Hoskin et al. 2016). Instead, in other Scandinavian countries airsoft pellet guns in Denmark (17.4%) and projectiles in Norway (21.5%) were the most common injury mechanism (Takvam & Midelfart 1993; Saunte & Saunte 2008). Floorball eye injuries has declined in junior players after Finnish Floorball Federation's decision to enforce protective eyewear mandatory (Leivo et al. 2015). Tools and nails have been reported to be common causes for eye trauma and for OGTs (McEwen et al. 1999; Tok et al. 2011). In our study, only three (1%) traumas were caused by tools (nails and a nail gun), but two of them were OGTs (Table 1). These may have been prevented with proper tool use. Other OGTs were caused by fireworks (2), ski pole and a gun (Table 1). Total amount of OGTs (6) during a one-year period in Finland is double compared with the Danish study by Vestergaard et al. (2015).

All firework-induced injuries were serious: two of four injuries were OGTs, one had traumatic cataract and one ischaemic area on the conjunctiva. Wearing protective eyewear might have prevented three of the traumas, but one bystander still had traumatic cataract despite using protective eyewear. In 2010, Finland legislated a new law prohibiting the handling of fireworks by those under the age of 18, restricting certain type of fireworks and reducing the duration of New Year firing season (Kivelä 2014). After that, firework accidents have diminished from 47 to 11 in 2014.

One-third (36%) of pellet gun accidents caused permanent disability and 82% required lifelong follow-up. They caused glare because of dilated pupil, cataract and lowered VA. In Denmark, the incidence of airsoft gun injuries was reported to be 3.1 per million in the 'under-18' age group (Saunte & Saunte 2006). In our data, the incidence is 8 per million in patients under 16 years of age. Only one child was using protective eyewear at the time of accident. At least seven of 12 accidents took place at the home or in the home yard. Distributing pellet guns to children is both the caregivers' and the sellers' responsibility. The dangerousness of pellet guns may not be sufficiently recognized in public knowledge because these guns might be conceived as toys. As shown in this study, current measures and supervision are insufficient.

Playing belongs to childhood and it should not be restricted too much. Children should, however, be advised about safe playing. All traumas are not preventable, but the high-risk activities, such as the use of pellet guns without protective eyewear, should be avoided. Use of protective eyewear would have prevented or diminished eye traumas in pellet gun, floorball, most of the fireworks and in many superficial FB, for example welding eye injuries. Although amount of firework accidents has decreased, the eye traumas caused by fireworks remain serious.

Fireworks and tools are not suitable toys for children. Pellet guns cause a significant amount of serious eye injuries; one-third of these injuries cause permanent disability and almost all create an elevated risk for glaucoma. The use of pellet guns should be restricted to specific areas where the use of protective eyewear is supervised.

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ORIGINAL PUBLICATIONS

TOY GUN EYE INJURIES – EYE PROTECTION NEEDED. HELSINKI OCULAR TRAUMA STUDY.

III

Acta Ophthalmologica

Acta Ophthalmologica 2019

Toy gun eye injuries – eye protection needed Helsinki ocular trauma study

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ABSTRACT.

Purpose: **We report the epidemiology, findings, treatment, long-term outcome and use of resources for eye injuries caused by toy guns in southern Finland.**

Methods: **All new patients injured by toy guns in one year (2011–2012) and treated at Helsinki University Eye Hospital were included. Follow-ups occurred at 3 months and 5 years.**

Results: **Toy guns caused 15 eye traumas (1% of all eye traumas). Most patients were male (n = 14) and children aged under 16 years (n = 13). Toy guns involved were airsoft guns (n = 12), pea shooters (n = 2) and paintball (n = 1). Eleven patients did not use protective eyewear, and four patients discontinued their use during the game. Seven patients were not active participants in the game. Blunt ocular trauma was the primary diagnosis in 13 patients and corneal abrasion in two. Seven patients had retinal findings. In the 5-year follow-up, eight of 15 patients had abnormal ocular findings: three had artificial intraocular lens, two iridodialysis, and one each retinal plomb, mydriasis or iris tear. None had glaucoma. Seven patients had permanent subjective impairment due to pain, lowered visual acuity, blur or difficulty in focusing. Four patients needed seven operations. The number of outpatient visits was 90. One patient required hospitalization.**

Conclusion: **Toy guns cause serious eye traumas. No glaucoma was found. Proper use of toy guns and protective eyewear during the whole game should be emphasized to both players and bystanders. We recommend that in Finland the selling of airsoft guns be placed under the Firearms Act to make the hazards of airsoft guns known.**

Key words: airsoft gun – eye injury – paintball – pea shooter – pellet gun – Toy gun

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Introduction

Toy guns are popular toys in children's play, likewise paintballs in adults' leisure time. Airsoft guns, also called pellet toy guns, resemble real guns in appearance and shoot 6 mm plastic pellets. Paintball pellets are larger, 17–18 mm spherical balls containing liquid (Nemet et al. 2016). Both can reach a velocity of up to 110 m/s (Duma et al. 2006; Kennedy et al. 2008). Pea shooters are often self-made. Without proper protective eyewear, toy guns pose a danger to eyesight due to their extreme energy.

A hit from a pellet typically causes blunt ocular trauma. Initial findings are often corneal erosion and oedema, bleeding in anterior chamber, vitreous, and retina, traumatic cataract, retinal commotion along with retinal and irideal tear and changes in intraocular pressure (IOP) (Fleischhauer et al. 1999; Saunte & Saunte 2006; Ramstead et al. 2008; Kratz et al. 2010; Jovanović et al. 2012; Haavisto et al. 2017). Globe ruptures have been reported from paintballs and also a few cases from airsoft guns (Greven & Bashinsky 2006; Adyanthaya et al. 2012; Jovanović et al. 2012; Nemet et al. 2016). Optic neuropathies have also arisen from paintballs (Thach et al. 1999). Traumatic glaucoma may present even years after a blunt ocular trauma (Kaufman & Tolpin 1974; Girkin et al. 2005; Ozer et al. 2007; Lee et al. 2017).

The incidence of toy gun eye injuries has been reported to be 0.3 eye injuries/100 000 population in Denmark (Saunte & Saunte 2006) and 2.5/100 000 in Israel (Kratz et al. 2010). In Hong Kong, 12% of all eye-injured paediatric patients were harmed by toy guns (Poon et al. 1998). Toy guns cause notable morbidity due to the lifelong risk for glaucoma for injured parties.

The few studies of toy gun eye accidents are often case reports or retrospective studies (Fleischhauer et al. 1999; Ramstead et al. 2008; Adyanthaya et al. 2012; Nemet et al. 2016), the follow-up is short (Saunte & Saunte 2006), and airsoft guns are not distinguished from other types of air guns (Lee & Fredrick 2015). To our knowledge, there are no long-term follow-up studies of toy gun-injured patients.

The aim of this study was to present the epidemiology, findings, treatment, long-term outcome and use of resources for eye injuries caused by toy guns in Finland.

Materials and Methods

Patients injured by projectile toy guns were identified in the Helsinki Eye Trauma Study, which comprehends all new eye trauma patients taken into care at the Emergency Clinic of Helsinki University Eye Hospital (HUEH) during a one-year period between May 1, 2011 and April 30, 2012. The HUEH is a tertiary and secondary eye care hospital, with a population base of 1.5 million.

Patients with eye injuries were prospectively identified in the emergency clinic. They were given a questionnaire about the trauma-causing event and circumstances. In the absence of the questionnaire, the information was gathered from hospital records. In addition, to identify all patients with eye injury, the hospital records were accessed and diagnoses indicating eye injury were verified directly or indirectly by ICD-10 diagnoses. Age, gender, laterality, possible amblyopia, detailed status findings at first visit, diagnoses and treatments were recorded from hospital records.

Eye traumas were divided into five primary diagnosis groups: blunt ocular trauma (BOT), wound in eyelid or periorbital area, orbital fracture, open globe trauma (OGT) and mild superficial trauma in the eye or periorbital area. Possible secondary and tertiary diagnoses were recorded. In case of binocular eye injury, the more seriously injured eye was observed.

In the first phase, three months after the trauma, visual acuity (VA), intraocular pressure (IOP) and clinically significant ocular findings were recorded. The need for lifelong follow-up and permanent disability were estimated, and the number of surgical procedures was recorded.

In the second phase, 5–6 years after the trauma, the patients were invited to a thorough eye examination including best corrected visual acuity (BCVA), IOP (ICare and Goldmann applanation tonometry), gonioscopy, slit lamp biomicroscopy and dilated fund examination. All patients underwent visual field (VF) examination by Octopus G dynamic program (Haag-Streit AG, Bern, Switzerland) or Goldmann in case of lack of co-operation. Peripapillary nerve fibre layer (NFL) thickness was measured using optical coherence tomography (OCT) (Heidelberg Engineering, Heidelberg, Germany). Stereo disc photographs and fundus NFL photographs were taken. In case of lack of co-operation, IOP was measured with Icare (Icare TAOi, Icare Finland Oy, Vantaa, Finland). Two patients were lost to follow-up. One of them was interviewed by telephone.

Resource use was estimated by the number of outpatient visits, duration of hospitalization and medication, number of operations performed, and need for sick leave or activity restriction. If the sick leave or sports restriction was not recorded, their need was estimated based on clinical findings and international recommendations (Recchia et al. 2002; Walton et al. 2002; Tsai et al. 2011; Gerstenblith & Rabinowitz 2012).

Injuries were classified by the Birmingham Eye Trauma Terminology System (BETTS) (Kuhn et al. 2004).Year was divided into four seasons: spring (March, April, May), summer (June, July, August), autumn (September, October, November) and winter (December, January, February).

The epidemiological data were analysed, distribution represented, and percentages calculated from the reported results.

The study protocol was approved by the Ethics Committee of the Helsinki-Uusimaa Hospital district and followed the tenets of the Declaration of Helsinki.

Results

Epidemiology

Fifteen eye injuries, 1% of all eye injuries (n = 1151), were caused by a toy gun over a one-year period. The annual incidence was 1.0 eye injuries/100 000 population taking into account all toy guns, 1.9/100 000 in males (0.1/100 000 in females). Taking into account only all airsoft guns the incidence was 0.8/100 000. Patients' age range was from 3 to 47 years (mean 14.7 years), with a male predominance of 93% (14/15). The majority of injuries (n = 9) took place during primary school age (7–12 years) (Fig. 1). Nine traumas were in the right and six in the left eye. There were no binocular traumas and none was in an amblyopic eye. No one had a second eye injury during the follow-up.

Twelve traumas were caused by an airsoft gun, two by a pea shooter and one by a paintball. The location of the hit is seen in Table 1. The main diagnosis was blunt ocular trauma in 13 patients (87%) and mild superficial trauma in two patients (13%). According to BETTS, all traumas were closed.

Most of the accidents occurred in the summer (n = 7), less in the autumn (n = 4), winter (n = 3) or spring (n = 1). Four accidents took place inside a house, ten outdoors, four of which occurred in a private courtyard. Information was lacking for one patient. Seven patients were playing a game during the accident, five were handling a toy gun outside an active game, two were bystanders and in one case the circumstances were unknown.

Protective eyewear was used by four (27%) of 15 patients, all during a game. The accident took place when the game ended (n = 2), while cleaning the glasses (n = 1) or when wrong-sized glasses had fallen (n = 1).

First visit and 3-month follow-up

Significant status findings initially and after 5 years are seen in Table 1.

At first visit, eight patients had VA less than 0.5 Snellen equivalent. One could not be defined because of young age. Three patients needed medication for elevated IOP for 2–6 weeks. Medication was started 0–21 days after the accident. The most significant findings were as follows: macroscopic or microscopic hyphema (n = 13), irideal trauma (n = 2), traumatic cataract (n = 1) and posterior findings (n = 7).

At the end of the 3-month follow-up, one patient was operated on for retinal tear and three for traumatic cataract. One patient had rebleeding 2 months after the accident and was treated with tranexamic acid. Four patients had VA 0.4 Snellen equivalent or less, and all had normal IOP. Thirteen patients were estimated to need a lifelong follow-up due to elevated risk for glaucoma after BOT. Five patients were estimated to have a permanent disability due to iridodialysis and glare (n = 2), lowered VA (n = 2), or lack of accommodation in young age because of an IOL (intraocular lens) (n = 1). No other operations were estimated to take place in future.

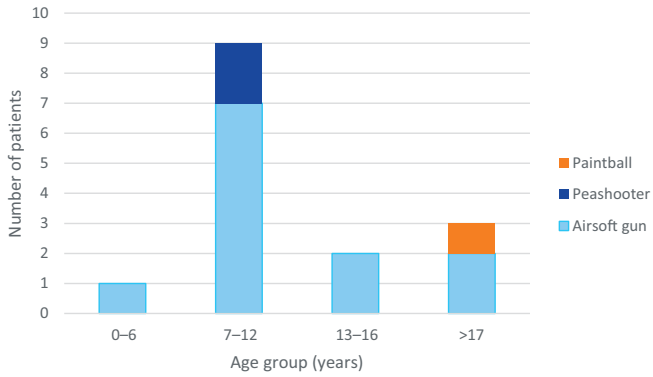

Fig. 1. Distribution of eye injuries and type of toy gun causing injury in different age groups.

5-year follow-up

Findings

At the 5-year follow-up, 8/13 patients had abnormal findings; seven were injured by an airsoft gun and one by a paintball. Pea shooters did not cause subjective impairment or abnormal findings, although one case was lost to follow-up.

BCVA was normal (0.9–1.5) in all but one patient who was injured by an airsoft gun and had only light perception without clinical explanation.

Of patients injured by airsoft guns, 7/12 (58%) had abnormal findings, including iridodialysis or torn iris (n = 3), IOL (n = 3), pigment in vitreous (n = 2), posterior capsular opacity (PCO) (n = 2), retinal plomb (n = 1) or mydriasis (n = 1).

The only paintball-injured patient had diffuse tearing in the iris stroma.

Glaucoma was not diagnosed in any patient, and IOP was normal (<22 mmHg) in all patients. Four patients had a few relatively nonglaucomatous depressions in Octopus VF testing. One patient had abnormal findings in Goldmann VF testing (suspected malingering); however, no difference was present in optic disc cupping between the injured and the healthy eye. Peripapillary NFL thickness was normal in all patients, and no defects were seen in NFL photographs.

Subjective impairment

Subjective impairment was reported by seven patients (47%), six of whom were injured by airsoft guns. Airsoft trauma caused pain (n = 4), blurred vision (n = 2), lowered VA (n = 1) and glare

Table 1. Significant status findings at first visit and in the 5-year follow-up. Patient number 5 was interviewed by telephone.

		BCVA		First visit						5-year-follow-up		
	Age	Initial	5 year	IOP	Dg	Location	Abnormal findings	IOP elevation	PD	Abnormal findings	Subjective impairment	Operated
Airsoft pellet gun												
1	11	0.1	1.1	17	BOT	Cornea	Iridodialysis	–	Yes	Iridodialysis	–	–
2	9	0.63	1.4	14	Abrasion	Cornea	–	–	–	–	–	–
3	10	0.7	1.1	9	BOT	Cornea	Macular oedema	–	–	–	–	–
4*	3	NA	1.0	17	BOT	Eyelid/ sclera	Retinal tear	–	Yes	Retinal plomb	Pain	Yes
5	47	0.5	NA	14	BOT	NA	Berlin oedema	–	–	NA	Blur	–
6	9	0.05	0.9	17	BOT	Cornea	–	–	–	IOL, pigment in vitreous	Pain	Yes
7	14	0.4	1.5	7	BOT	Cornea	Iridodialysis, retinal bleeding and oedema	–	Yes	Iridodialysis, pigment in vitreous	Pain	–
8	9	CF	1.0	21	BOT	Cornea	Cataract	Yes	Yes	IOL, PCO	Blur	Yes
9	14	CF	1.25	21	BOT	Cornea	–	–	–	–	–	–
10	12	0.4	1.25	14	Abrasion	Eyelid/ cornea	–	–	–	–	–	–
11	11	0.4	1.1	22	BOT	Cornea	Berlin oedema	Yes	–	IOL, sphincter rupture	–	Yes
12	21	0.1	LP	16	BOT	Cornea	Macular oedema, vitreous bleeding	–	Yes	Mydriasis	Low VA, glare, pain	–
Pea shooter												
13	11	0.8	NA	32	BOT	Limbus	–	Yes	–	NA	NA	–
14	8	1	1.5	12	BOT	Eyelid	–	–	–	–	–	–
Paintball												
15	32	0.6	1.0	18	BOT	Eyelid	Berlin oedema	–	–	Tears in iris	Focus	–

BCVA = best corrected visual acuity; BOT = blunt ocular trauma; CF = counting fingers; Dg = main diagnosis; IOL = intraocular lens; IOP = intraocular pressure; LP = light perception; NA = data not available; PCO = posterior capsule opacity; PD = estimated permanent disability; VA = visual acuity.
* Female.

(n = 1). Pain was described in three patients to be occasionally recurring, lasting from a few seconds to up to three days. In one patient, pain was more severe and almost constant and along with lowered VA and glare caused impairment. The patient injured by a paintball had difficulty in focusing.

Operations and use of resources

Altogether seven operations were performed on four patients, all of whom were injured by airsoft guns; the operations comprised three cataract surgeries (one additional cataract surgery and PCO opening were needed after the 3-month follow-up), one retinal cryo-coagulation, one retinal plomb insertion and two PCO removals. Traumatic cataracts were operated on 1–7 months, retinal cryo-coagulation 4 weeks and retinal plomb insertion 11 weeks after the trauma. Posterior capsular opacity (PCO) openings were performed 3 and 11 weeks after cataract surgeries. There were 90 outpatient visits and one hospitalization day.

Discussion

This is the first population-based long-term follow-up study of toy gun eye accidents in Finland presenting the epidemiology, clinical findings, diagnoses, treatments, outcomes and resource use for toy gun eye injuries.

Our study reveals that the majority of toy gun accidents are serious. Initially, blunt ocular trauma was diagnosed in 13 (87%), posterior findings in seven (47%), iridodialysis in two (15%) and cataract in one patient (7%). At the 5-year control, eight patients (62%) had abnormal clinical findings: IOL in three (20%), iridodialysis or irideal tearing in four (27%), retinal plomb in one (7%) and mydriasis in one (7%). Subjective impairment was reported by seven patients (54%). Altogether seven operations were performed on four patients.

A weakness of our study is the small number of patients. However, almost all patients (13/15, 87%) attended the 5-year re-examination.

The incidence of airsoft gun accidents has been reported infrequently. In our study, the incidence of 0.8/100 000 patients is in accordance with previous studies. In Israel, the incidence of 2.5/100 000 (Kratz et al. 2010) is markedly higher than in our study or in Denmark 0.3/100 000 (Saunte & Saunte 2006). According to Kratz et al. (2010), in Israel airsoft guns are purchased without any age restriction, which may explain the higher incidence. We also found that toy guns comprised less (6%) of all children's eye accidents in Finland than reported in Hong Kong (12%) (Poon 1998).

The mean age of airsoft and pea shooter patients (13.5 years) was less than that of the paintball patients (32 years). In previous reports of airsoft patients, the mean age has varied from 9.8 years to 18 years (Fleischhauer et al. 1999; Saunte & Saunte 2006; Ramstead et al.2008; Kratz et al. 2010). In the studies of Saunte & Saunte (2006) and Fleischhauer et al. (1999), the age, 13 years and 13.9 years, respectively, is similar to ours. In paintball studies, the mean age has been 16–22 years (Thach et al. 1999; Fineman et al. 2000; Greven & Bashinsky 2006; Baath et al. 2007; Nemet et al. 2016). Consequently, the mean age in our study is consistent with earlier reports, and airsoft guns and pea shooters appear to be more popular among younger people than paintballs.

Airsoft guns produced similar clinical findings here as in previous studies: posterior findings in 47% versus 12.5–55.6% and traumatic cataract in 23% versus 1.7–33.3% of patients (Fleischhauer et al. 1999; Saunte & Saunte 2006; Ramstead et al. 2008; Kratz et al. 2010). The follow-up time in earlier studies ranged from a mean of 6.5 days (1–54 days) (Saunte & Saunte 2006) to a mean of 8.8 months (0.5–24 months) (Fleischhauer et al. 1999). The short follow-up time may explain the low incidence (3.0%) of traumatic cataracts found by Saunte & Saunte (2006), although the lowest incidence of 1.7% was reported by Kratz et al. (2010) who had a follow-up of 7.6 months. It is noteworthy that in our study all three cataract patients were operated on when they were aged under 12 years, therefore, lacking normal accommodation.

Irideal trauma was found in 33% of our patients, which is similar to traumatic mydriasis in 25–44% and iris dialysis in 21% of patients in previous studies (Fleischhauer et al. 1999; Ramstead et al. 2008; Saunte & Saunte 2008; Kratz et al. 2010; Staffieri et al. 2010).

Paintball eye accidents have yielded several devastating findings, from globe ruptures to optic neuropathies (Thach et al. 1999; Greven & Bashinsky 2006; Nemet et al. 2016). Our study included only one paintball-injured patient who was diagnosed with central retinal oedema and irideal tear and had subsequent difficulty in focusing.

Pea shooters induced two traumas. One patient had BOT, hyphema and elevated IOP; this patient was lost to follow-up. Another patient had BOT with normal IOP, and in the 5-year follow-up the status was normal. We found no previous studies concerning pea shooters. However, it is meaningful to note that even pea shooters can produce severe eye trauma.

Interestingly, glaucoma was not found in any of the patients despite thorough examinations and a relatively long follow-up. One patient diagnosed with BOT, hyphema and elevated IOP had a potential risk for glaucoma, but was lost to follow-up. Altogether, 40% (n = 6) of patients had either traumatic cataract or injuries to the iris or both. In the study of Sihota et al. (1995), traumatic cataract, especially with iris trauma, was associated with an increased risk for glaucoma. In their prospective review of 100 patients with trauma-associated glaucoma, all patients had two of the following: traumatic cataract, angle recession more than 180 degrees, significant iris trauma or displacement of lens. Glaucoma was diagnosed at 1 month to over 20 years after the trauma. A long follow-up is therefore needed since glaucoma may present even decades after the eye trauma.

With two exceptions, all patients with abnormal clinical findings (five of seven patients) had also subjective impairment. This is two more than estimated at 3 months after the accident. Four patients complained of pain, which is unfortunate, particularly in view of their young age. In one patient, the pain was more intense and presented together with distinctly lowered VA and glare. There was no obvious reason for pain of any of the patients. In one patient, impaired focusing hindered the photography

hobby. Blurry vision was described by two patients: one (interviewed by telephone) while bending and the other in the temporal side of the visual field, possibly due to PCO. Glare was described by only one of five patients with irideal trauma. We found no earlier studies reporting subjective impairment of toy gun-caused eye injuries in long-term follow-up.

Although four patients (27%) in our study used protective eyewear during the game (three airsoft, one paintball), the glasses had been abandoned at the time of the accident because of discomfort; the protective eyeglasses were described as too big, dirty or misty. Similarly, Fineman et al. (2000) had noted that 60% of patients harmed by a paintball had initially been wearing protective eyewear, but 86% had removed them; 33% because of fogging and 17% because of paint splatter. Compliance in using protective eyewear would increase if they were more comfortable.

In our study, 53% (n = 8) of accidents took place outside of organized war games; two of the patients were bystanders and in six cases a toy gun had been used outside of an agreed game. The toy gun had been used, for instance, at home, believing that the gun was not loaded when aimed at someone. In the study of Greven & Bashinsky (2006), 47% of paintball eye injuries occurred outside official or unofficial war games and included also assaults. There were no assaults in our study. The dangerousness of toy guns outside games appears to be unrecognized, leading to their irresponsible use.

In Finland, airsoft guns are classified as airguns, but product marketing and the safety of toy guns and protective equipment are controlled by The Finnish Safety and Chemical Agency. Sellers are advised to inform buyers about the regulations and hazards. If airsoft guns were to fall under the Firearms Act, their hazards might be better understood. In arranged airsoft and paintball games, specific protective eyewear is obligatory (pks-airsoft.net). In Denmark, the law prohibits the use of pellet toy guns by persons aged under 18 years (Saunte & Saunte 2006).

Toy guns cause serious eye traumas, although no glaucoma was found in Finnish patients in the 5-year follow-up. More attention should be paid to improving the usability of protective eyewear. Proper use of toy guns and protective eyewear throughout the game should be emphasized to both players and bystanders. We recommend that in Finland the selling of airsoft guns be placed under the Firearms Act to make the hazards of airsoft guns known.

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ORIGINAL PUBLICATIONS

EYE INJURIES CAUSED BY WOODEN PROJECTILES IN FINLAND. HELSINKI OCULAR TRAUMA STUDY.

IV

EYE INJURIES CAUSED BY WOODEN PROJECTILES IN FINLAND – HELSINKI OCULAR TRAUMA STUDY

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Key words: Stick, branch, wood, eye trauma, eye injury

Running title: Wooden projectile-caused eye injuries in Finland

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ABSTRACT

Aims The aim of this study is to report the current population-based epidemiology, treatment, use of resources and outcomes of eye injuries caused by sticks, branches and other wooden projectiles in Finland.

Methods: The study included all new patients injured by wooden projectiles with eye or eye socket traumas over a one-year period. Patients were treated at the Helsinki University Eye Hospital, which covers a population of 1.5 million. The follow-up time was three months.

Results: Wooden projectiles caused 67 eye injuries and compromised 6% of all new eye traumas during a one year. Of the patients, males predominated (76%) and 22% were children aged under 17 years.
Injury was most likely in spring (36%) or autumn (27%) and in males aged 51-67 years.
The most common activity during the accident was playing (27%), gardening (18%) and forest work (16%).
Diagnoses were mild superficial trauma (54%), blunt ocular trauma (not penetrating eyeball) (37%), eyelid wound (4%), orbital fracture (3%) and open globe (penetrating eyeball) trauma (1%).
Permanent disability was estimated for 10% and a need for lifelong follow-up was estimated for 37%.

In relation to time spent in each activity, the highest risk for eye injury was in gardening, forest work and woodwork.
The number of outpatient visits was 167 and inpatient days 30. Eleven patients needed major surgeries.

Conclusions: Wooden projectiles cause serious eye injuries, permanent disability and need for lifelong follow-up. More caution is required to protect the eyes when playing with sticks and during gardening, forest work and woodwork.

BACKGROUND

Wood as an independent cause of eye injury has rarely been the sole focus of studies. However, we know that among children sticks cause 7 -27 % of eye traumas in Finland, 12% in Brasil and up to 27% in Nigeria (1-3). In Denmark, 33% of children's penetrating eye traumas and in adults in Finland 4% and in Canada 6% have arisen from wooden items (4-6). Among geriatric patients, wood strike was the most common reason for penetrating eye trauma in Turkey (7).

Wooden material causing eye and intraorbital injuries have varied from branches and sticks to pencils, bamboo sticks and corn stalks in previous studies (4,8-10). As an organic material, untreated wood entails a risk for serious infections. Case reports are published on intraorbital, intraocular and surface infections from uncommon bacteria and fungi (10-12). On the other hand, in a few larger studies no particular type of organism predominated and no mycobacteria or fungi were found (8,9).

AIMS

To our knowledge, there are no recent studies in Europe or in the Nordic countries on eye injuries caused by wooden items. The aim of this population-based study was to present epidemiology, findings, treatment and use of resources for eye injuries caused by branches, sticks and other wooden materials in urban and rural areas of southern Finland over a one-year period.

METHODS

The Helsinki ocular trauma study includes all new eye trauma patients taken into care at the Emergency Clinic of Helsinki University Eye Hospital (HUEH) over a one-year period from 1 May 2011 to 30 April 2012. The HUEH is a tertiary and secondary eye care hospital, with a population base of 1.5 million. This study includes all patients injured by wooden items, e.g. sticks and branches. Excluded from the study were patients injured by wooden dust, cosmetic wooden items and matchsticks.

Patients were prospectively identified in the emergency clinic and requested to fill out the questionnaire. In addition to locating all patients with eye injury, the hospital records were accessed and diagnoses indicating eye injury directly or indirectly by ICD-10 diagnoses were verified.

A patient questionnaire inquired about the circumstances and causes of the accident, use of protective eyewear, influence of alcohol and whether the injury was intentional. An informed consent was obtained from patients or their caregivers. In the absence of the questionnaire, the information was gathered from hospital records. Additional information, including the involved eye, age, sex, possible amblyopia (poor vision from birth), detailed clinical findings at the first visit and diagnoses, was recorded from hospital records. The follow-up time was 3 months. The record from the last visit included the final visual acuity (VA), intraocular pressure (IOP) and significant findings.

Severity of the eye trauma was evaluated by estimating the need for lifelong follow-up, by performed surgery and estimated future surgery and by permanent disability due to abnormal VA or other functional symptoms.

Eye traumas were divided into five primary diagnosis groups: ‘blunt ocular trauma’, ‘wound’ referring to wound in eyelid or area surrounding the eye, ‘orbital fracture’, ‘open globe trauma’ (OGT) or group ‘other’ referring to mild superficial trauma in the eye or periorbital area. Clinically, the most significant ocular trauma or the one needing most health care resources was chosen as the primary diagnosis. Possible secondary and tertiary diagnoses were recorded. In case of binocular eye injury, the more seriously injured eye was selected. The energy of the trauma was evaluated as high-energy, if tools or falling was involved.

Resource use was estimated by gathering information about the number of outpatient visits, duration of hospitalization and medication, number of operations performed, need for sick leave or activity restriction. If sick leave or sports restriction was not recorded, the need for these was estimated based on clinical findings and international recommendations (13-16).

Activity during the accident was categorized and divided into gardening, play, woodwork, forest work, outdoor recreation or sport. Woodwork referred to working with wood as a hobby or at work. Forest work was chosen when the trauma took place during silviculture work, e.g. harvesting wood and planting. The incidence rates of eye injuries in each activity was calculated from time spent (person minutes in a one-year period) spent in each activity. Data were available for patients 10 years of age or older. Confidence intervals were calculated by exact method (17,18).

Because some activities are seasonal in Finland, the year was divided into four seasons. Epidemiological data were analysed, distribution presented, and percentages calculated from the reported results.

The study protocol was approved by the local ethics committee and followed the tenets of the Declaration of Helsinki.

RESULTS

Wooden projectiles caused 67 eye traumas, which is 6% of all new eye traumas treated at HUEH in a one-year period. Of the patients, 76% (n=51) were males and 22% (n=15) children under the age of 17 years. The incidence was 4.4 /100 000 population (18). An eye injury was most likely in males aged between 51 and 67 years (n=24) (Figure 1). Two patients were lost to follow-up.

The injury was equally common in the left and right eye. No binocular traumas or traumas in an amblyopic eye occurred.

More injuries occurred during spring (36%) and autumn (27%) (Figure 1). Accidents took place at home (55%, 93% outside the house), at outdoor sites (12%), at school or day care (10%) and at work sites (8%). Data were not available for 16 patients.

There were no known intentional traumas. Alcohol was involved in three injuries of males aged 25-26 years. Protective eyewear was used by one patient while working with a table saw.

Activities

The most common activities were playing (27%, n=18), gardening (18%, n=12) and forest work (16%, n=11) (Table 1). The activity could not be determined in nine traumas. Children were injured during play (n=14) and gardening (n=1). At play, the accidents took place when someone threw (n=4), a child swung (n=4) or someone hacked (n=2) a stick, while climbing in trees (n=2) or while kick boarding (n=1). In one patient, a corneal infection scar remained in the cornea. Bacterial, fungal and viral cultures were negative.

While gardening, an 87-year-old male fell and was diagnosed with OGT and orbital fractur. Eventually the eye was removed (eviscerated). Other gardening traumas were caused by a hit from a branch.

In forest work, three patients were using an axe, one a billhook and one a saw. In outdoor recreation, one trauma was caused by stumbling in the woods and others were hits from branches. During the woodwork working with table or circular saw (n=3), axe (n=1), poking a window tab (n=1) and building a fence for horses (n=1) caused eye injuries. In sport, injuries were caused by a crash on a bike and in orienteering of a hit from a branch.

High energy was involved in 15 injuries (22%) (Table 1). All were adults, with males predominating (n=13, 87%). Tools were used in ten cases and falling was a mechanism in five.

When comparing the number of eye traumas in relation to time used for activity, the risk was highest in gardening, followed by forest work and woodwork (Table 2).

Diagnoses, treatment and use of resources

The most common primary diagnoses were superficial trauma in eyeball or in area surrounding the eye or periorbital trauma (n=36, 54%) and blunt ocular trauma (n=25, 37%) (Table 1). Clinically significant secondary diagnoses were in 16 % of patients (n=11).

Major surgeries were needed for 10 patients (15%). One patient, probably in need of orbital surgery, was lost to follow-up. High energy was involved in four cases. Five patients were estimated to need surgery in future. All injuries involved tools or falling.

The number of outpatient visits was 167 (range 1-12 / 67 patients, mean 2.5), hospitalization days 30 (range 1-9 days / 9 patients, mean 3.3 days) and sick-leave days 405 (range 1-54 days / 40 patients, mean 10.4 days) for patients aged over 16 years. Medication was needed for a total of 983 days (range 3-90, mean 16.4 days) for 60 patients, two for elevated IOP.

Three-month follow-up, permanent disability, need for lifelong follow-up

VA was lowered (0.5 Snellen equivalent or less) in four patients. Three months after the accident, two patients were medicated for elevated IOP.

Permanent disability was estimated for seven patients (10%) because of lowered VA (n=3), diplopia (n=2), evisceration(n=1) and glare due to dilated pupil (n=1). Activities were various. High energy was involved in

five cases. Tools were used in two cases, in forest work and woodwork. No children under the age of 17 years had permanent disability (Table 1).

Need for lifelong follow-up was estimated for 25 patients (37%) because of risk for elevated eye pressure in future (glaucoma) (n=24) and evisceration (n=1). The most common activities were playing, gardening, forest work and woodwork. High energy was involved in ten cases. Tools were used in seven cases, in forest work and woodwork–caused injuries. Six patients were children under the age of 17 years.

DISCUSSION

This is the first study to present a wide variation of eye injuries caused by wooden projectiles. We present a comprehensive population-based longitudinal study over a one-year period from Southern Finland. In this unique study, we can analyse the outcome of wooden projectile-caused eye injuries in relation to cause in urban and rural areas of Southern Finland.

A few limitations are noteworthy. Firstly, the number of patients is relatively small for statistical analysis. Secondly, the short follow-up may affect the evaluation of permanent disability. A longer follow-up would likely have a positive impact since VA may improve after treatment and double vision may diminish over time. On the other hand, traumatic glaucoma may develop even years after the incident. However, obvious disabilities, such as evisceration and glare, can be seen in the three-month follow-up.

Interestingly, we found that spring was the most common season for wooden projectile eye injuries. Longer daylight in spring in Finland increases the possibility and enthusiasm for outdoor activities and also increases the time spent in gardens.

In our study, an eye injury was most common in males aged 51-64 years. Patients were older than in previous studies (8,9). In Finland, older men seem to be in the greatest danger; they may be more active participants in forest work and gardening.

Playing, gardening and forest work were the most common activities. In the study of Tas & Top (2014), forest work, assault and falling were the most common activities causing intraorbital wooden foreign bodies. Compared with our study, there were no assaults, but falling was involved in four cases.

In relation to time spent in each activity, gardening, forest work and woodwork were estimated to include the biggest risk for eye injuries. The use of tools possibly explains the increased risk in woodwork and in forest work. In gardening, only one patient used a tool (wood chipper) and another fell. The short working distance to branches may increase the risk for eye injuries Also, the use of protective eyewear is not routine. Since 12 out of 18 patients injured during playing were younger than 10 years, playing was not analysed.

Permanent disability and need for lifelong follow-up were caused by various activities, but not by playing. Need for lifelong follow-up was not related to high-energy traumas only and involved also children. In two blunt ocular traumas causing permanent disability, the activity could not be defined.

A special interest in previous studies has been in intraorbital wooden foreign bodies. The incidence for these is rare and also in our study only one patient had an intraorbital wooden foreign body (8-10). A challenge in wood-induced eye traumas is the difficulty in identifying wood in radiological imaging. This may delay diagnosis and treatment (10,12,19-23). Also, in our study the radiological finding was reported as “air in intraorbital space”, but since wood was suspected the report was corrected.

In our study, only one keratitis was diagnosed. Several reports of infections caused by wooden materials exist (10). In many cases, the diagnosis was delayed, with the wooden intraorbital or intraocular foreign body identified only after infection (8,9,11,12). However, the incidence of wood-associated orbital or ocular infections or keratitis has not been reported. According to our study, bacterial infections are rare.

Playing is essential for children and playing with sticks is ubiquitous. Playing should not be restricted excessively, but care should be taken when playing with sticks. Fortunately, playing with sticks did not cause any permanent disabilities. Nevertheless, seven children need lifelong follow-up because of an elevated risk for glaucoma.

Contrary to expectation, use of protective eyewear did not prevent eye injury while working with a table saw. However, use of eye protection would likely have prevented or diminished eye injuries in woodwork and forest work, activities in which tools are commonly used. In addition, some accidents occurred unexpectedly in activities where eye protection is not generally an issue. More attention should thus be focused on eye injuries when working with tools or in forestry.

With 70% of Finland's area comprising forests, eye injuries, especially from sticks and branches, may be more common than in many other countries.

CONCLUSIONS

Our study shows that wooden projectiles cause various eye injuries in a wide range of circumstances, resulting in permanent disability and need for lifelong follow-up for many patients, including children. Most of these injuries are preventable and more attention should be directed to use of eye protection, especially during gardening, forest work and woodwork. Children should be guided in playing safely with sticks.

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Figure 1. Age and seasonal variation of patients injured by wooden projectiles.

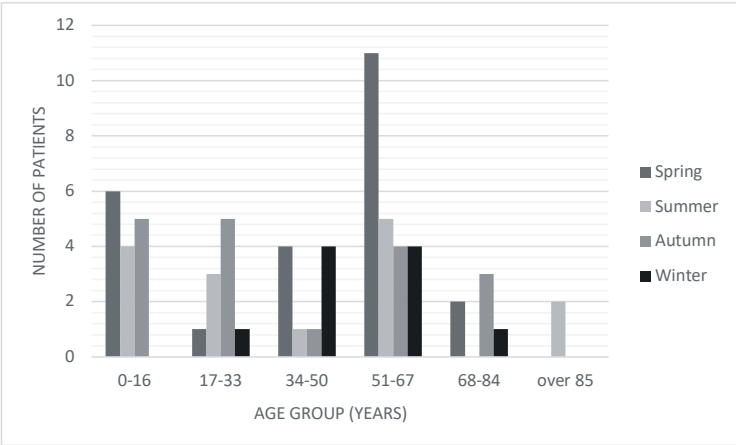

Table 1. Primary diagnoses, permanent disability and need for lifelong follow-up caused by wooden projectiles in relation to activity. Eleven patients had significant secondary diagnoses.

	All	BOT	Wound	Fracture	OGT	Other	Permanent Disability	Need for lifelong follow-up
Play	18 (27%)*	7	2	-	-	9	-	7 (39%)†
Gardening	12 (18%)*	4	-	-	1	7	1 (8%)†	5 (42%)†
Forest work	11 (16%)*	6	1	-	-	4	1 (9%)†	5 (45%)†
Outdoor recreation	8 (12%)*	1	-	-	-	7	1 (13%)†	1 (13%)†
Woodwork	6 (9%)*	5	-	-	-	1	1 (17%)†	5 (83%)†
Sport	3 (4%)*	-	-	2	-	1	1 (33%)†	-
Unknown/Other	9 (13%)*	2	-	-	-	7	2 (22%)†	2 (22%)†
Total	67	25	3	2	1	36	7 (10%)	25 (37%)
Work-related	4 (6%)*	3	-	-	-	1	-	3
High-energy	15 (22%)*	9	1	1	1	3	5	10

BOT = Blunt ocular trauma (not penetrating eyeball).
OGT = Open globe trauma (penetrating eyeball).
Other = Mild superficial trauma in the eye or periorbital area.
*Percentage calculated from the total number of eye injuries (n=67).
†Percentage calculated from the number of activities.

Table 2. Risk for eye injury caused by wooden projectiles in different activities in relation to time spent in each activity. The time period is one year.

Activity	IR*	(95% CI)
Gardening	6,51	(3,36-11,37)
Forest work	5,51	(2,75-9,85)
Woodwork	3,00	(1,10-6,54)
Outdoor recreation	1,45	(0,62-2,85)
Cycling	0,54	(0,01-2,42)
Skiing	0,43	(0,01-2,42)
Orienteering **	1,08	(0,03-6,04)

*) Per 1 000 000

**) Included one patient